chromasens
Imaging for Professionals

3DPIXA | General Introduction

CD40116 Version 1

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1 About Chromasens

The name of our company, Chromasens, is a combination of 'chroma' which means color, and 'sens' which stands for sensor technology.

Chromasens designs, develops and produces high-quality and user-friendly products:

- Color line scan cameras
- 3D stereo line scan cameras
- Multi-spectral line scan cameras
- Camera systems
- Camera illumination systems
- Image acquisition systems
- Image processing solutions

1.1 Contact Information

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Visit our website at http://www.chromasens.de for detailed information on our company and products.

2 3DPIXA at a Glance: Product Overview

The 3DPIXA is a stereo camera using line scan technology and provides color images and 3D height data at the same time. The tri-linear RGB color sensor of the 3DPIXA camera provides high resolution color images. Both, high resolution and high speed imaging is the advantage of line scan cameras.

The following diagram gives an overview of available 3DPIXA cameras*

Feature	3D-PIXA-C15-A	3D-PIXA-C30-A
Optical resolution	15 µm / pixel	30 µm / pixel
Scan width	40 mm	105 mm
Number of Pixels per line	2660 pixels	3500 pixels
Max. line frequency	22 kHz	22 kHz
Depth of field (focused image)	1 mm	3 mm
Height range (depending on material)	Up to 3 mm	Up to 10 mm

*Other resolutions are available on request.

The 3DPIXA is based on the allPixa color line scan camera from Chromasens. Please see the description of all camera features and parameters in the allPIXA manual.

2.1 3DPIXA Highlights

- Factory calibrated stereo line scan camera with one sensor
- High optical resolution with 15 µm and 30 µm
- Trilinear color line scan camera (trilinear CCD line scan sensor)
- 10 µm pixel size
- High accuracy sensor and lens alignment
- Maximum data rate of 170 MPx/s (24Bit RGB) – 510 MB/s

3 Introduction of Stereo Imaging (Stereo Vision)

The 3DPIXA stereo camera is based on the line scan camera allPIXA and provides stereo images in color. The stereo images are transferred via CameraLink to a frame grabber in a computer (PC). The height data are calculated from these stereo images by the 3DPIXA software running on the GPU in the PC. The results are the height map, the rectified color image and the 3D point cloud.

3.1 Stereo Principle

Getting height information from stereo images is based on the triangulation principle: the same object is captured with two cameras providing two images, a left and a right one, of the same object. In other words, one point on the object surface has two corresponding image points: one in the right and one in the left image.

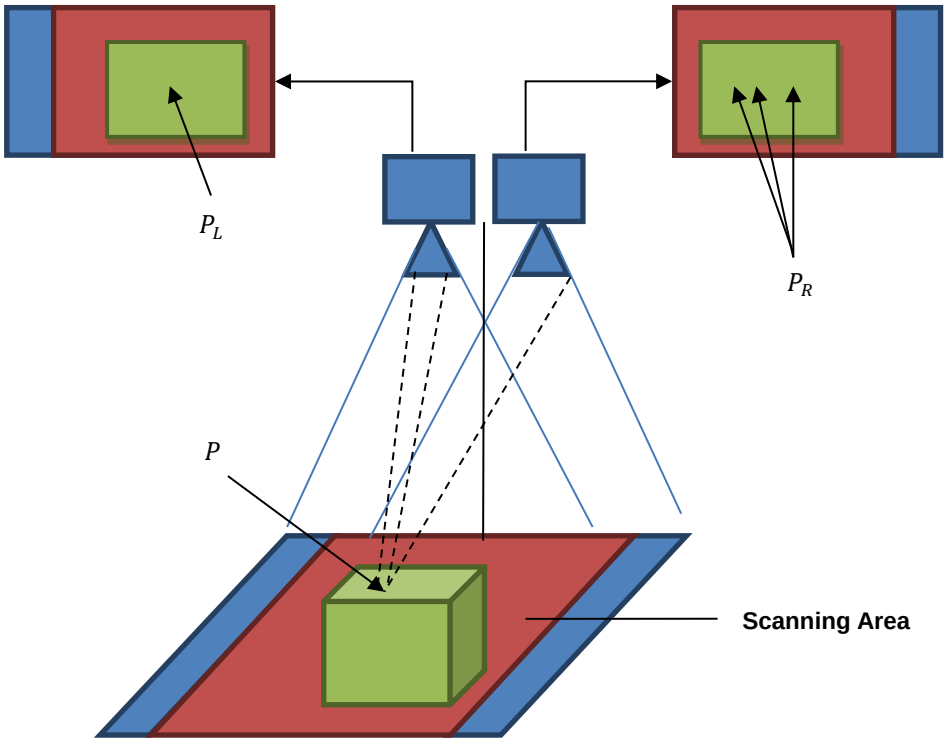


Figure 1: Stereo Principle

For calculating the height of an object point, we first have to identify the corresponding two image points P_L and P_R. A pattern matching approach is used to find the corresponding points. The pattern matching is performed for each image point of the left image P_L and runs on graphical processing units (GPU) to get high performance for keeping up with the line frequency of the camera (real time).

In the second step the distance (disparity) of the two corresponding image points is measured with sub pixel accuracy. Each pair of corresponding image points results in a disparity value in the disparity map. In the third step the height is determined from the disparity map using the calibration data of the setup.

3.2 Epipolar Line

In general the two images from the two stereo cameras are slightly different, e.g. in optical resolution and orientation. The pattern matching algorithm works best if these misalignments are corrected.

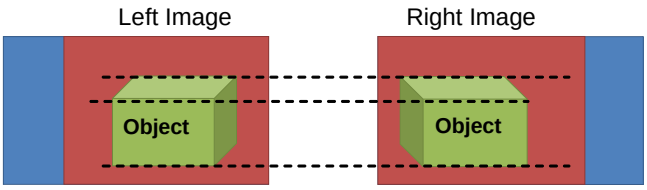


Figure 2: Aligned Stereo Images

There is a two-step approach done during production to achieve best similarity:

- The first step is the adjustment of the sensors, cameras and the lenses to get the best orientation possible of the two images.

- In a second step the deviations are meassured, the correction data is caculated and stored in the calibration data.

This is done with each camera during factory calibration.

3.3 Pattern Matching

For pattern matching a correlation based approach is used. For each image point in one image (e.g. left image) a small window surrounding this point is taken as a pattern.

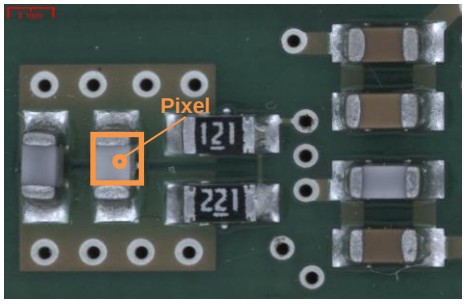


Figure 3: Left image with template

For this pattern the correlation is performed for all image points in the expected height range (determined by the min and max disparity setting) in the other image.

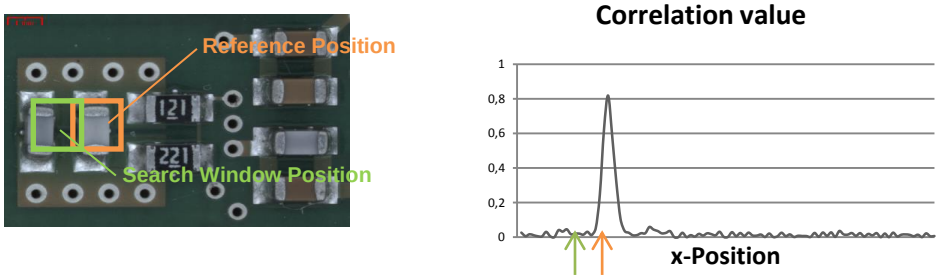


Figure 4: Right image with search window at disparity min position

The correlation results a score for the degree of matching for each image point in the expected height range.

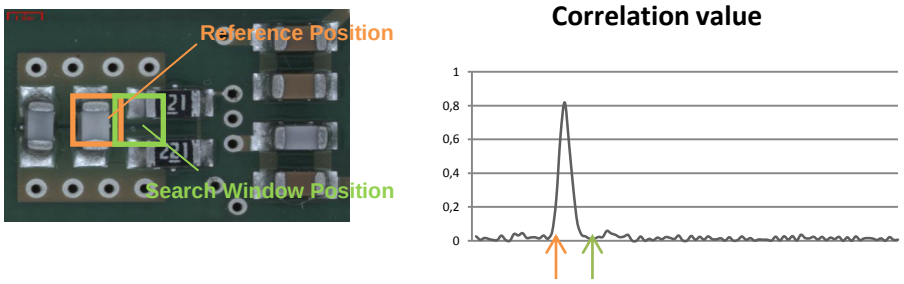


Figure 5: Right image with search window at disparity max position

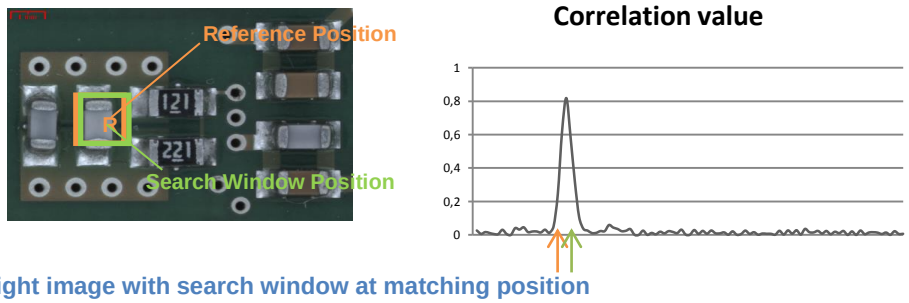


Figure 6: Right image with search window at matching position

The highest score gives the position of the best match. The position-shift of these two image points is called the disparity.

For pattern matching both images should be almost identical. To achieve this, evenly and homogeneous illuminated and perfect focused images are very important.

3.3.1 Parameter for Adjusting the 3D Calculation

There are a few parameters for the optimization of the matching algorithm and the further processing of the 3D data:

- the window-size
- the maximum and minimum disparity (corresponding to the expected height-range)
- the minimum correlation factor
- additional system parameters

For information about how to adjust the parameter we refer to the documentation of CS-3D-Api and the CS-3D-Viewer. Also it is strongly recommended to try different combinations of parameters, using our interactive CS-3D-Viewer.

3.4 Calibration

The 3DPIXA is factory calibrated. The calibration data for each camera is determined using a special calibration procedure.

For each 3DPIXA there is a calibration data set which is provided with the 3DPIXA.
The calibration data reflects the internal and external geometry of camera and lens(es).

4 Surface and Illumination

Textures in the images are an important pre-condition for the passive stereo approach. To make the structures of the surface visible in the image the interaction of the surface properties and illumination is crucial.

4.1 Optical Surface Properties

Diffuse reflecting surface	Mirror like surface: specular reflection
 Figure 7: Diffuse reflecting Surface	 Figure 8: Mirror-like Surface

Most of the object surfaces are a mixture of these both types of reflections.

4.2 Illumination

The illumination can be optimized for the given application. This is one advantage of 3D stereo imaging over the laser line approach. Furthermore the following advantages of the line scan camera will take effect:

- Uniform illuminated line
- Very low distortion of lens
- No distortion in transport direction
- Balanced shading
- No occlusion in transport direction

In order to get the best results for the height map, both stereo images should be almost identical. Hence, evenly and homogeneous illumination is very important to end up with reliable and accurate height data.

5 Setting up Camera and Illumination

5.1 Mounting

Please be sure to adjust the distance of the camera to the object according to the drawing in chapter 6.6.1 or 6.6.2, since the depth of field is in the range of about 1 – 3 mm. The right distance of the camera to the object results in sharp images, see Figure 9 and Figure 10.

Figure 9: Blurred image

Figure 10: Sharp image

If the interesting parts of the surface are not completely within the depth of field that's not necessarily a problem. The matching algorithm also works on a bit blurry images, but maybe with a bit loss of accuracy. Figure 11 illustrates the dependency between sharpness and accuracy.

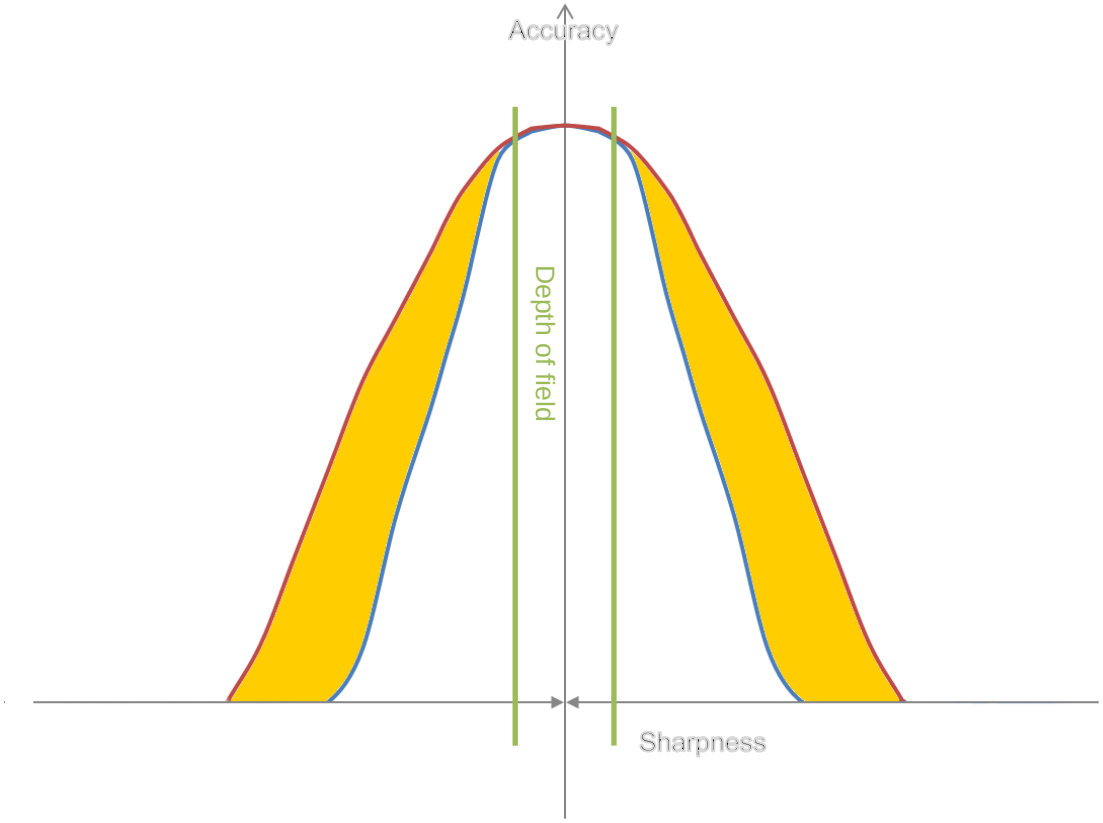


Figure 11: Dependency between Sharpness and Accuracy

The curve may vary, depending on how the structures on the surface change through blurring, but the maximum accuracy will always be in the depth of field.

5.2 Camera Parameters

Please refer to the allPIXA manual for setting up encoder and trigger signals.

5.3 Illumination Types

For each object surfaces there is an optimal illumination setting to minimize the specular reflections and maximize the visibility of the structures of the surface. Also it is important that the structures visible in the left and the right image look similar, so the algorithm can find the correspondences.

5.3.1 Bright-field Illumination

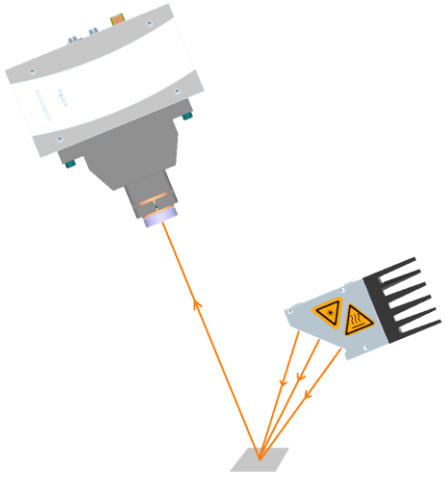


Figure 12: Bright Field Illumination

- The reflecting portion of the incoming light goes directly into the camera.
- Bright image
- Good visibility of most structures

5.3.2 Dark-field Illumination

- The bigger portion of the incoming light is reflected away of the camera.
- Mainly the light scattered by the structure of the surface goes into the camera.
- Brightness of the camera image highly depends on the structure of the surface

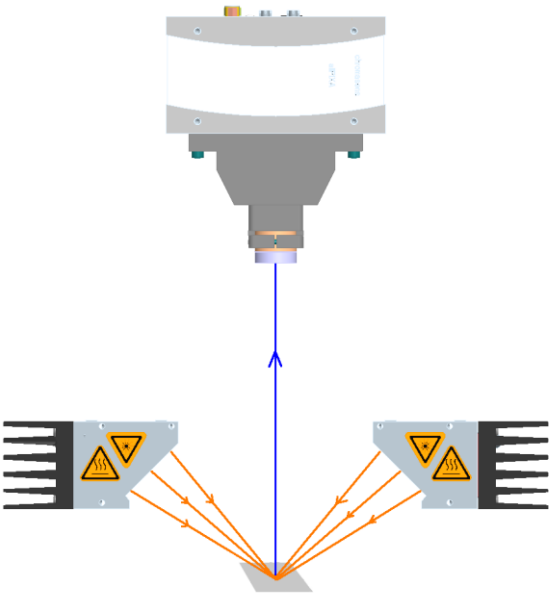
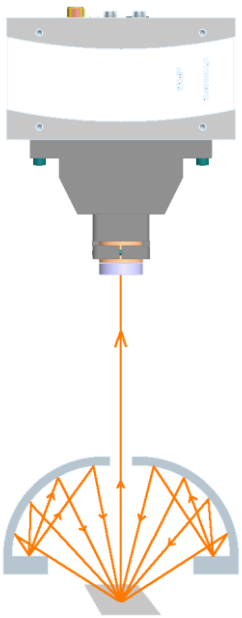


Figure 13: Dark Field Illumination

5.3.3 Cloudy Day (Dome) Illumination



- Light beams illuminate the surface from many different angles
- Very diffuse and homogenous illumination
- Reduces shadow casting
- Contrast depends on structure of the surface

Figure 14: Cloudy Day (Dome) Illumination

5.3.4 Coaxial Illumination

- The object surface is illuminated with parallel light beams
- Reduced shadow casting
- More illumination intensity is needed, because the semi-transparent mirror only has a 50% reflectance.

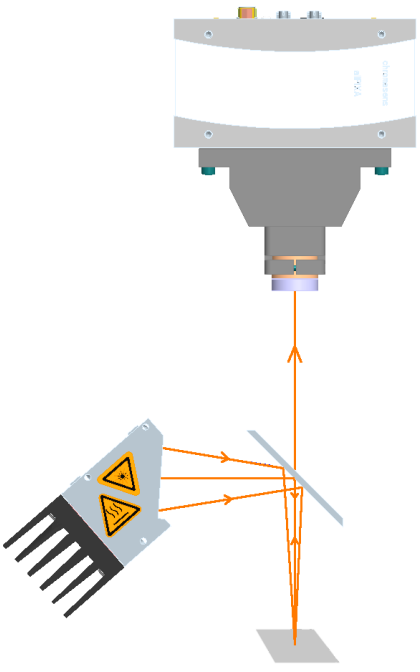
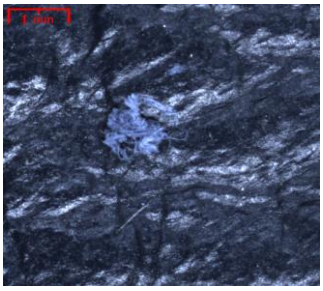
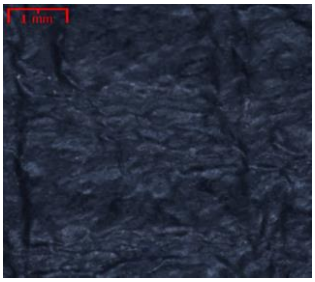
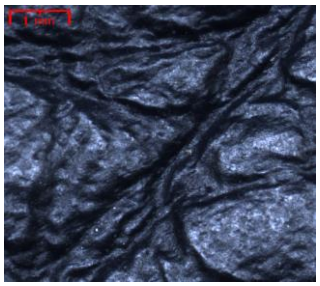
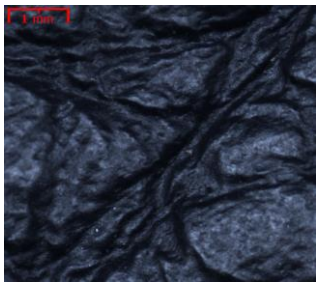
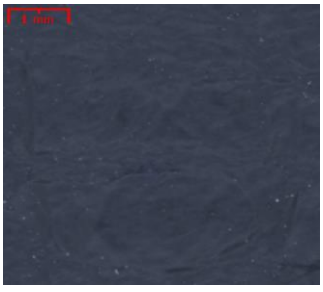


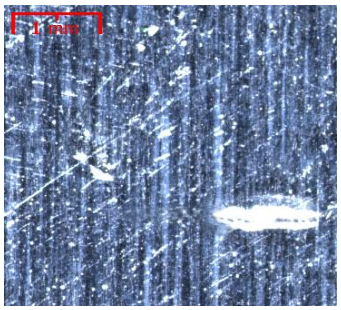
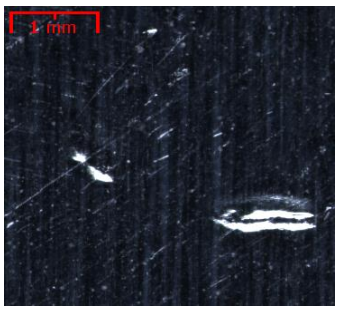
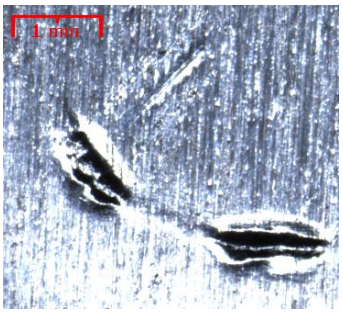
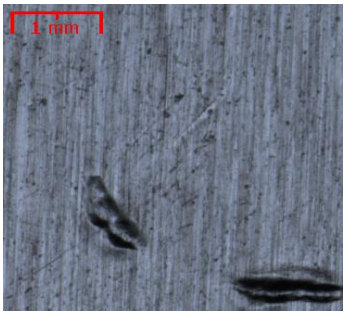
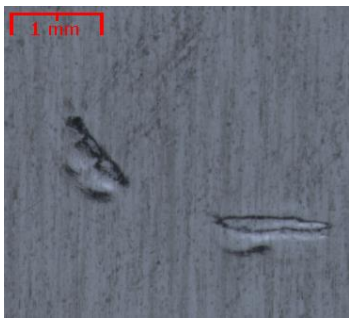
Figure 15: Coaxial Illumination

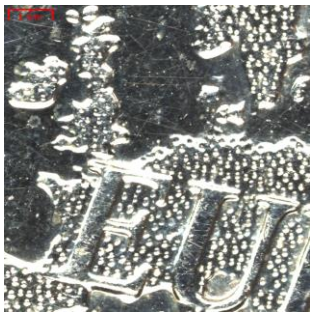
5.3.5 Choosing the Right Illumination

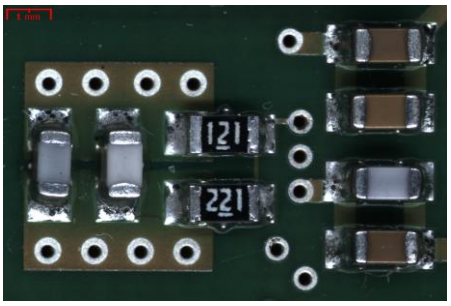
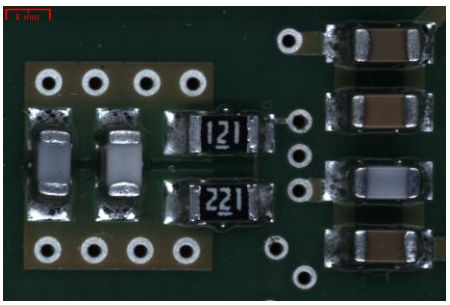
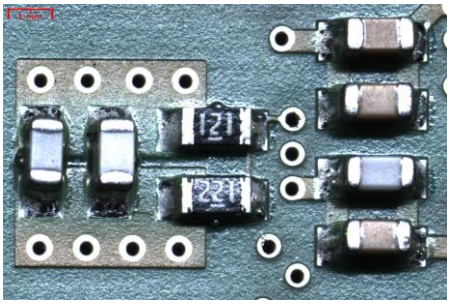
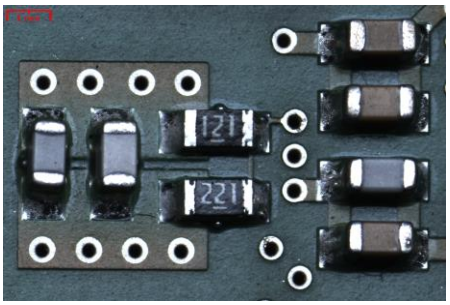
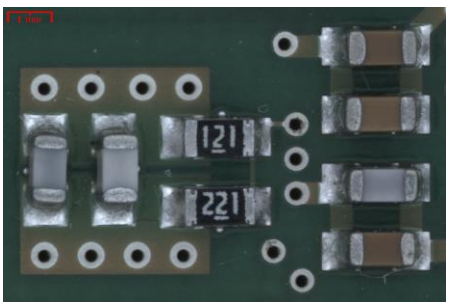
With the best illumination all details of the object surface structure are visible in the images.

		Object surface			
		Diffuse	Metal surface	partly specular	Complex / combined
		Example of object			
Type of illumination	Light intensity	Leather	Brushed aluminum	Coin	Electronic board
Dark field	++	++	-	-	++
Dark field diffuse	+	++	-	-	++
Bright field	++	++	-	O	O
Bright field diffuse	++	++	++	++	+
Dome	+	+	++	+	++

Type of illumination	Light intensity	Example of object	Object surface
		Leather	Diffuse
Dark field	* * *		
Dark field diffuse	* * *		
Bright field	* *		
Bright field diffuse	* *		
Dome	* * *		

Type of illumination	Light intensity	Example of object	Object surface
		Brushed aluminum	Metal surface
Dark field	* * *		
Dark field diffuse	* *		
Bright field	*		
Bright field diffuse	*		
Dome	* *		

Type of illumination	Light intensity	Example of object	Object surface
		Coin	Partly specular
Dark field	* * *		
Dark field diffuse	* * *		
Bright field	* *		
Bright field diffuse	* *		
Dome	* *		

Type of illumination	Light intensity	Example of object	Object surface
		Electronic board	Complex / combined
Dark field	* *		
Dark field diffuse	* *		
Bright field	* *		
Bright field diffuse	* *		
Dome	* *		

6 General

6.1 CST – Camera Setup Tool

Updates can be downloaded from our website at http://www.chromasens.de.

Please proceed to the “Partner” area.

For login a registration is needed.

Before you install and use the CST, please check whether a new CST or manual version are available.

If you already have an installed version of the CST, you can view the version number in the *Help* menu.

The use and the functions of CST are described in the allPixa manual at chapter **“10 CST – Camera Setup Tool”**

6.2 CS-3D-Software Package

The package includes

- 3D-Api for the calculation of the disparity / 3D data
- Examples regarding the integration of the Api
- The Chromasens 3D Viewer for visualization of 3D data and for interactive adjustment of the 3D calculation parameters.
- Manuals for the 3D-Api and the Viewer

6.3 Firmware and Software Version in this Manual

This document refers to the following version:

CS-3D-Software: 1.02

Camera-FW: 1.3m

Newer versions will have additional features. Please contact our support for more details about new features.

6.4 Scope of Supply for the 3DPIXA

Please check your device upon delivery to ensure that it is undamaged and complete.

The following components are supplied with the 3DPIXA.

- 3DPIXA packaging

  Please check the packaging for damage which may have occurred during transport.

- 3DPIXA stereo color line scan camera

  Please check the camera for damage which may have occurred during transport.

  The rating plate is located on the rear of the 3DPIXA. It shows the camera resolution and the serial number.

- CD – ROM / USB stick
  - Manuals
    - 3DPixa manual (this document)
    - 3D-software documentation
    - allPixa manual
    - HSI (Hardware-Software-Interface) documentation
  - Software
    - CST (the parameter programming software of the allPixa and the 3DPIXA)
    - CS-3D-Software package
    - HIS (for direct communication with the camera, without the CST)

- Additionally ordered and supplied components accessories

  Additional components and accessories like illumination are not included in the standard scope of delivery. These items must be ordered separately.

  Please check additionally ordered components and accessories for completeness and damage which may have occurred during transport.

Please read this manual carefully before using the camera or contacting Chromasens support.

If anything is unclear, or should you have any further questions, please do not hesitate to contact us. We would be pleased to be of assistance.

6.5 Technical Data of Camera

	3D-PIXA-C30-A	3D-PIXA-C30-A
Lateral Resolution	15 µm	30 µm
Optical Resolution	2 x 2,664 pixel	3,500 pixel
Sensor Resolution	7,300 pixel	
Sensor	Trilinear CCD color line sensor	
Pixel size	10 µm x 10 µm (10 µm pitch)	
Line spacing	40 µm between R-G and G-B	
Maximum data rate on the Camera Link	170 megapixels/s 24Bit RGB | 510 Mbytes/s	
Maximum line frequency	22.1 kHz	
Spectral sensitivity	360 nm to 960 nm	
Video signal	3x8 bit on Camera Link, 3x14 bit ADC	
Interface	CameraLink medium with 85 MHz	
Line scan operating mode	Free-running / external trigger (incremental encoder / line trigger)	
Other interfaces	Power supply (6 pin Hirose, male) External IO (15 pin D-Sub, female) Serial RS-232 (9 pin D-Sub, female)	
Power supply	24 VDC +/- 10 %; 1A; typical 16 W	
Temperature range	0° C to 50° C	
Housing dimensions (LxWxH)	130 x 102 x 90 mm	113 x 102 x 90 mm
Weight	~ 2 kg	

NOTE Depending on the power supply the power consumption might be up to 1 ampere for a short time at power up. It's recommended to provide a power supply with 24VDC/1amp or with higher possible power consumption.

6.6 Mechanical Dimensions of the 3DPIXA

6.6.1 Mechanical Dimensions of 3D-PIXA-C15-A

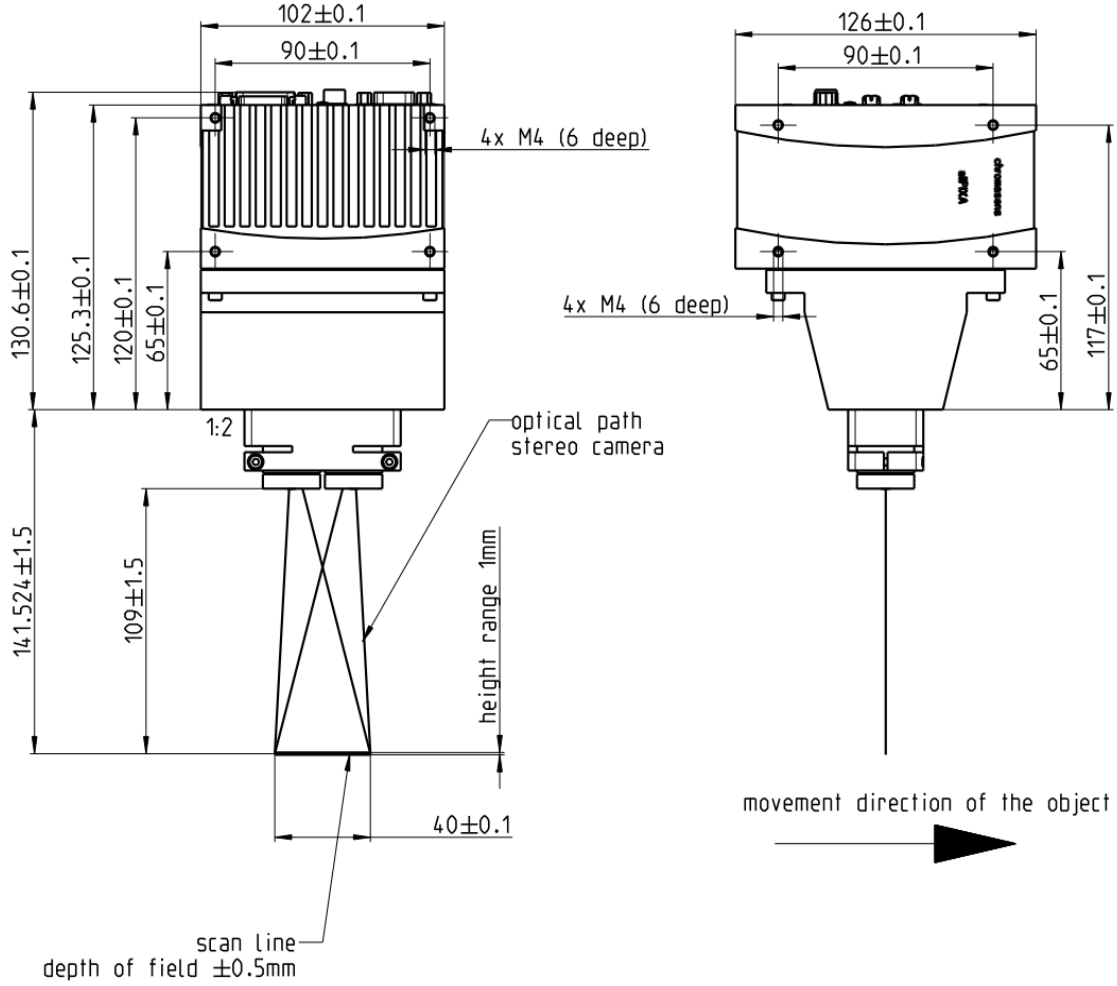


Figure 16: Mechanical Dimensions of 3D-PIXA-C15-A

NOTE I	Drawings and 3D-CAD-models are available on our homepage www.chromasens.de/partner
NOTE II	For XYZ coordinate system and for sensor alignment please refer to chapter 8.2 Design of the allPIXA line scan sensor and sensor alignment

6.6.2 Mechanical Dimensions of 3D-PIXA-C30-A

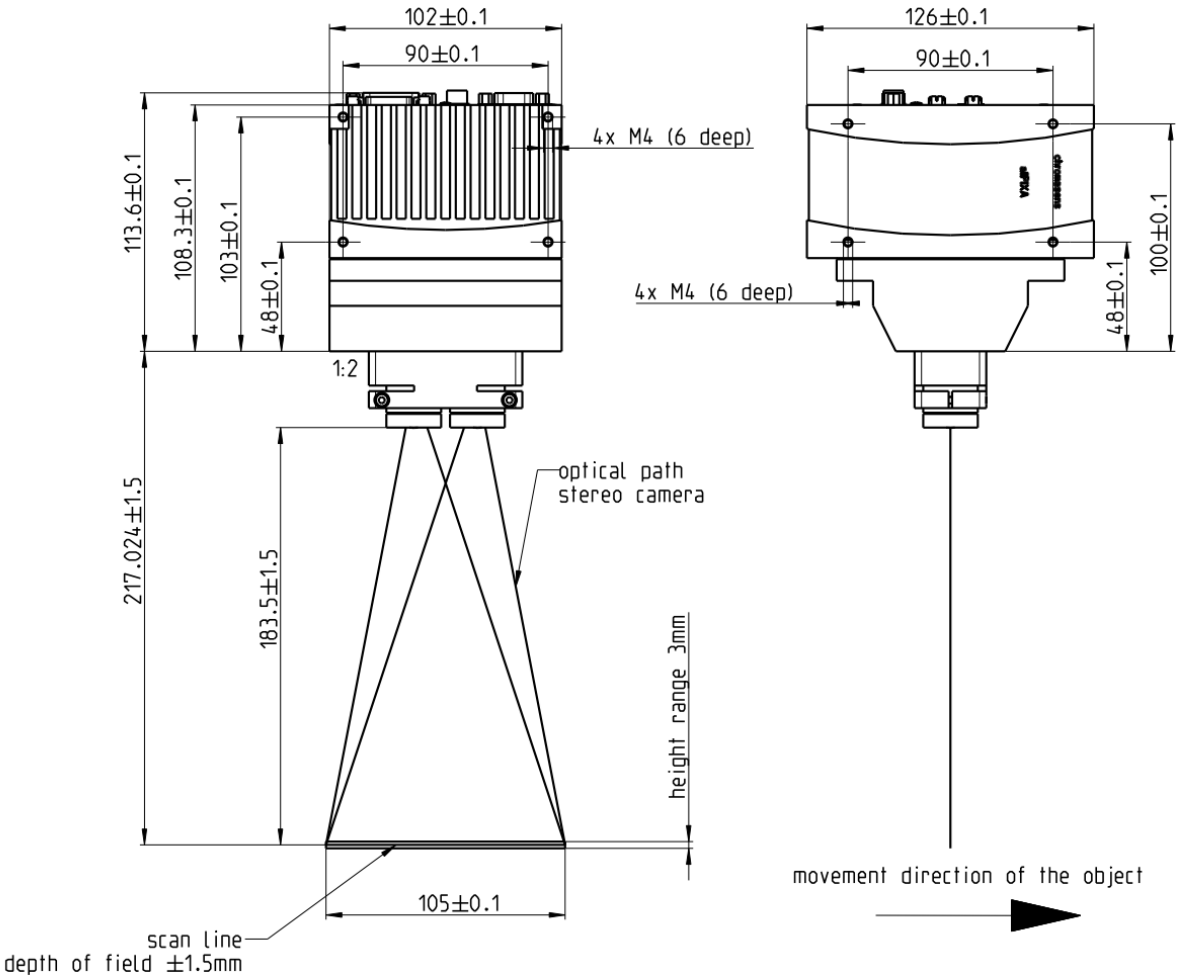


Figure 17: Mechanical Dimensions of 3D-PIXA-C30-A

NOTE I	Drawings and 3D-CAD-models are available on our homepage www.chromasens.de/partner
NOTE II	For XYZ coordinate system and for sensor alignment please refer to chapter 8.2 Design of the allPIXA line scan sensor and sensor alignment

6.7 Ambient Conditions

	Value
Ambient temperature during camera operation	0º C – 50 ºC
Air humidity during camera operation	20% - 85% relative air humidity, non-condensing
Storage / transport temperature	-20 ºC – +85 ºC
Protection category	IP50
General ambient conditions	
Operation	IEC 721-3-3:IE33
Transport	IEC 721-3-1:IE11
Storage	IEC 721-3-2:IE21

6.8 Legend

Definition	Explanation
Disparity	Difference between pixel position in left and right image, caused by projecting one object point through two different objectives
Shading correction	Corrects brightness inhomogeneity resulting from lens, illumination and non-uniformity of sensor pixels
RGB line distance	The tri-linear sensor has individual pixel lines for red, green and blue. Inside the camera the spatial differences are corrected.
White balancing	White balancing ensures that a reference white is kept stable in an image with color temperature or brightness changes in the illumination. This can be done in an onetime single setup process or continuously.
White reference	The white reference is a physical patch in the field of view of the camera that can be used for a camera internal white balancing.
Dongle	USB-Device used for software copy protection

6.9 Abbreviation

Abbreviation	Explanation
API	**A**pplication **P**rogramming **I**nterface
CST	**C**amera **S**etup **T**ool
CS	**C**hroma**S**ens
GPU	**G**raphical **P**rocessing **U**nit

7 Safety

7.1 Depiction of Safety Instructions

Safety-relevant information is indicated in this manual as follows:

WARNING

Indicates a potentially hazardous situation or task, which, if not avoided, could result in serious injury or death.

CAUTION

Indicates a potentially hazardous situation or task, which, if not avoided, may result in minor or moderate injury.

NOTICE Indicates a potentially hazardous situation or task, which, if not avoided, could result in damage to the product or the surrounding environment.

7.2 Presentation of Extra Information which is not Relevant to Safety

NOTE Provides additional information

7.3 Basic Safety Regulations

Always observe the following:

- Do not attempt to install the device or start operation before you have read all supplied documentation carefully and have understood its contents.
- Safe and correct operation of the device requries correct and appropriate transport, storage, mounting and installation as well as careful operation and maintenance.
- Operation of the 3DPIXA device is only permitted when it is in a faultless and safe condition. In the event of a fault or defect, the 3DPIXA or the machine or system in which the 3DPIXA is installed must be stopped immediately and the person responsible informed.
- Modifications and extensions to the 3DPIXA are only permitted if the prior written consent of Chromasens GmbH is obtained. This applies in particular to modifications and extensions which can negatively affect the safety of the 3DPIXA.
- Compliance with the ambient conditions described in this manual is essential.

7.4 Safety Instructions on the 3DPIXA

Risks from hot surfaces

The body of the 3DPIXA will heat up during operation.

Do not touch hot surfaces without suitable protective gloves. Always allow hot surfaces to cool down before carrying out any work on the unit.

Electric voltage hazard

The 3DPIXA runs with electric power. Before any work is carried out on the 3DPIXA, always disconnect all mains cables. Always make sure that the device is safely isolated from the power supply!

Risk of electrostatic discharge

The 3DPIXA contains components and units which are sensitive to electrostatic charge.

Observe all precautionary measures for handling electrostatically sensitive equipment.

Make sure that the 3DPIXA, all tools and the person handling the equipment have the same electrical potential.

7.5 Purpose / Applications

- The 3DPIXA is designed for installation in machines and systems which are used for commercial and industrial applications.
- The owner of the machine or system in which the 3DPIXA is installed is responsible for compliance with relevant safety regulations, standards and directives. Commissioning of the 3DPIXA is not permitted until it has been verified that the machine or system in which the 3DPIXA is installed complies with the safety regulations and standards of the country in which the 3DPIXA is run.
- The owner of the machine or system in which the 3DPIXA is installed must verify the suitability of the 3DPIXA for its intended use.
- The safety regulations of the country in which the device is used must be complied with.
- The 3DPIXA may only be connected or used as described in this manual.
- The 3DPIXA must be set up and installed in compliance with the instructions contained in this manual.

7.6 Personel Requirements

- The system owner must ensure that all persons working on the system are trained for the required work and have read and understood this manual. This applies in particular to personnel who only work occasionally with the 3DPIXA, for example during commissioning and maintenance work.
- Work on the electrical installations of the system may only be carried out by a qualified electrician or persons who have undergone electrotechnical training under the supervision of a qualified electrician in compliance with applicable electrotechnical regulations.
- Only suitably trained and qualified persons are permitted to work with the 3DPIXA. Such persons are qualified to work with the 3DPIXA device if they are familiar with its assembly, installation and care as well as all necessary precautionary measures.
- The assignments and responsibilities of personnel charged with operation, commissioning, maintenance and repair must be clearly defined. This definition must be specified by the owner of the machine or system in which the 3DPIXA is installed.

7.7 Organisational Measures

- The operating manual must always be kept in the vicinity of the camera when it is in operation.
- The information contained in this manual must be integrated into the documentation of the machine or system in which the 3DPIXA is installed.
- The 3DPIXA and all connected periphery must be checked regularly for visible, external damage.

7.8 Safety Instructions for Maintenance / Cleaning

- All personnel working on the system must be informed before service or maintenance work is carried out.
- Deadlines and intervals for regular inspection work must be complied with.
- Before starting maintenance work, the 3DPIXA must be isolated from the power supply.
- Devices that are heat sources such as heaters, radiators or lighting equipment must first be allowed to cool down, as there is the risk of burns.
- Only technicians of Chromasens GmbH are permitted to open or slacken screws or housing sections of the 3DPIXA
- Repair work may only be carried out by Chromasens GmbH.
- Clean the device with a soft, lint-free cloth and isopropanol (optional).
- To prevent damage to the camera, it may only be transported in its original packaging.