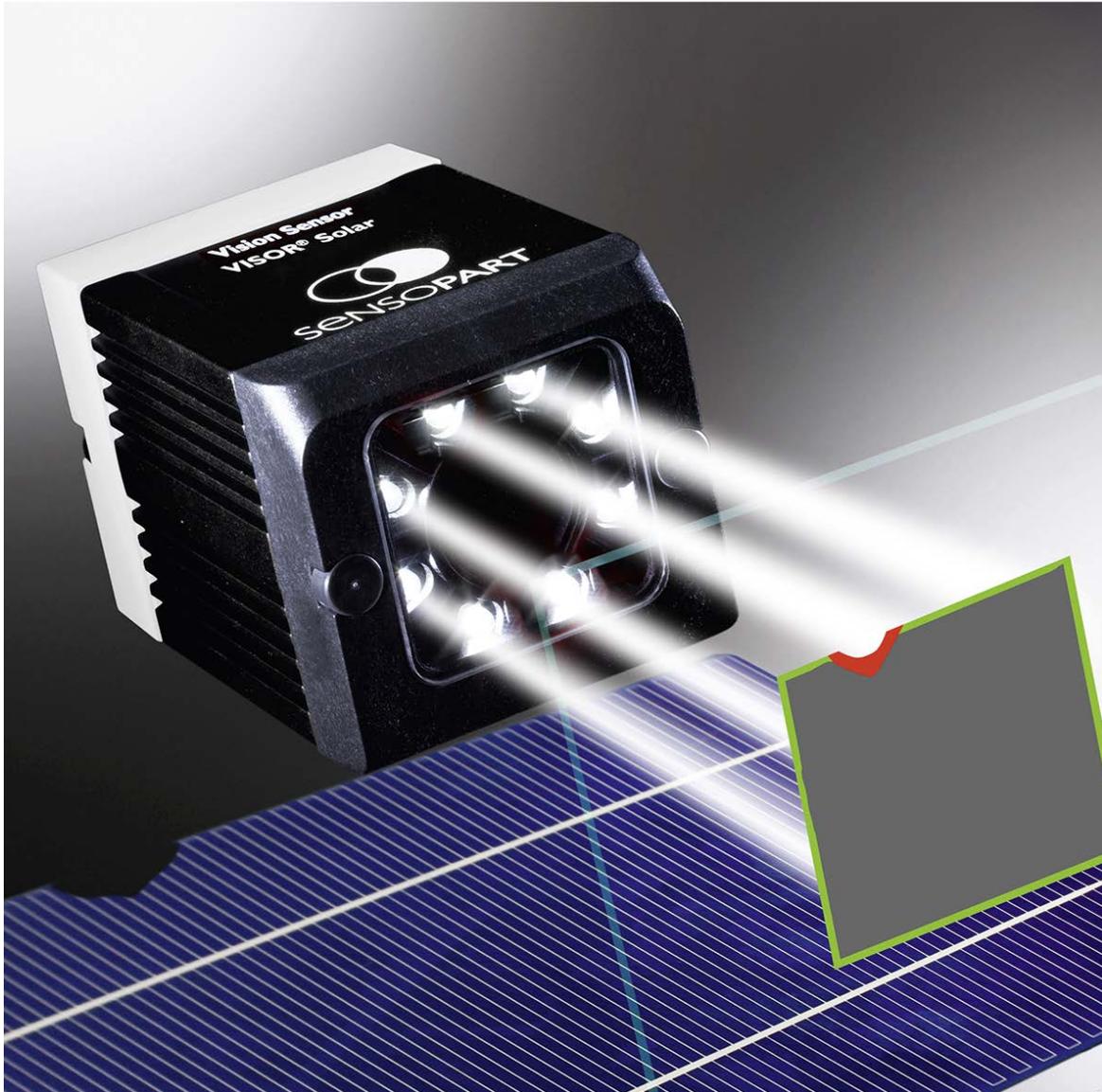




## *VISOR® Solar User Manual*



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**General remark**

All data shown is based on tests under laboratory conditions. It is necessary to confirm the results of our tests under process conditions to achieve process stability. Therefore, SensoPart provides demo samples and recommends to use this opportunity for final application evaluation.

Please use the data shown as a recommendation only. Your individual process environment such as ambient light, heterogeneous reflection behaviour of your products, colour, variability of inspected goods, repeatability of parts and feeding processes et cetera need to be considered within your final solution. Please consider space requirements, accuracy and stability of the positioning of optical systems, communication protocols to your PLC (Ethernet, sequential, digital) and timing within your process as well.



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## 1 Purpose of this user manual

The VISOR® Solar sensors are dedicated products developed to meet the needs of the silicon wafer production, cell handling and module fabrication. They include the functionality of a camera, a powerful illumination and fast data processing unit to provide an integrated stand-alone solution. The vision sensors provide precise positioning tasks with real world 50 µm accuracy and all established quality checks. The products are extremely easy to use and can be configured using established terms of the photovoltaic industry. Moreover, any square / rectangular products can be inspected

The knowledge of machine vision is NOT a necessary precondition. However, choosing the right set-up requires an overview of the abilities of the camera, which this user manual is targeting to provide. It guides users from their specific application to select the best fitting products and tools to implement them for highest accuracy, stability and convenience.

For further details on the products please refer to the corresponding datasheets and documents, or contact our technical support team – all listed in section “*9 Useful links and contacts*”.

## 2 Applications covered by VISOR® Solar sensors

### 2.1 Key features

Since silicon wafers are extremely fragile and have to be handled frequently before becoming solar cells, they have to be checked with regard to the following properties:

- **Wafer and cell position: X,Y and angle**  
Absolute accuracy better than 50 µm and a repeatability of a few microns can be obtained. Following this user manual, best performance for cell inspection, robot pick and place of the cells is obtained.
- **Wafer and cell dimensions**  
Measuring the wafer dimensions the sensor makes sure 5 and 6 Inch material is not mixed. Due to the accuracy of 100 µm double layers of two wafers can be detected to be sorted out.
- **Chips, which may cause a breakage of the cell**  
The edges of wafers may be damaged during handling forming chips. Chips from 0.5 mm in size can be either identified due to their size or due to their shape. The sensor is able to distinguish between comparatively harmless 'mouse bites' and severe 'shark teeth' defects.
- **Holes**  
Holes formed during the manufacturing of the ingot or block with sizes down to 0.02 mm<sup>2</sup> can be detected.
- **Busbars position, pads**  
The position of the busbars is correctly identified for tabber / stringer tools and for electrical tests like cell sorting or electroluminescence.
- **Cell type identification**  
Different cell types can be identified due to the number and spacing of busbars, the presence of pads and manufacturer logos. Moreover, the correct identification of the upper surface can be detected.

The availability of the functions for each camera model is described in section "3.1 Product lines".

## 2.2 User benefits

The sensors are designed for industrial usage withstanding even harsh conditions. Due to the integration of the illumination into the camera and a standardised set of mounting accessories the integration into machines becomes an easy task. CAD files can be found on our website.

- **Easy integration, cost-efficient solution**

The key objective of the product line is to provide robust and reliable wafer and cell analysis on a stand-alone solution with minimal integration efforts for the user.

The internal illumination was developed so even sunlight shielding becomes obsolete. Most of the tasks like position and chip detection can be provided without any costly backlight. Instead the internal high power LEDs are used in conjunction with a dedicated cost-effective reflective foil. Another important benefit is the small working distance of just 350 mm when testing 6 Inch wafers. Thus, the sensor requires very limited space which is scarce in actual production equipment. The sensor can be triggered via a digital I/O signal or via an Ethernet command. In the *Advanced* version additionally an encoder input is available to provide a high position accuracy when using conveyor belts with varying speed.

- **High flexibility, versatile product family**

The product family comprises of a wide range of models. The complete product line shares the same software, tools and accessories. All mechanical dimensions are identical.

Depending on the requirement of the cell makers machines can be upgraded easily with best-fitting camera model with almost no development efforts. Concluding, the wide product line of the VISOR® Solar provides highest flexibility and cost-effective production tools available on the world vision market today.



Figure 1: Typical lab setups using VISOR® V10-SO and an inexpensive reflective foil RF775. The position is detected from a distance of just 350 mm without any daylight protection.

Left tool comprises of MP45, MST45-40, MG45, MST45-20, MB45, MA45 and MK45.

## 2.3 Interfaces

The sensors run on 24V DC industrial power supplies and provide short-circuit proof digital I/O. For data such as position measurement the fully integrated ethernet or a serial bus connections may be used. The protocol is easily configurable and can be adapted to almost any PLC. A trigger signal may be sent as a digital input or via Ethernet. Data can be pulled by a server or transmitted by the sensor via FTP or SMB.

An "Engineering level *SensoConfig*" software is provided for the configuration and setup, whilst for easy overview and job selection the "Operator level *SensoView*" provides live images and statistics. In addition to these there is also a 3 level password protection built in to stop unauthorised changes being made.

## 3 Component selection

The VISOR® Solar product family comprises of different models sharing a wide range of illumination and lens options, so all physical mounting possibilities are ensured.

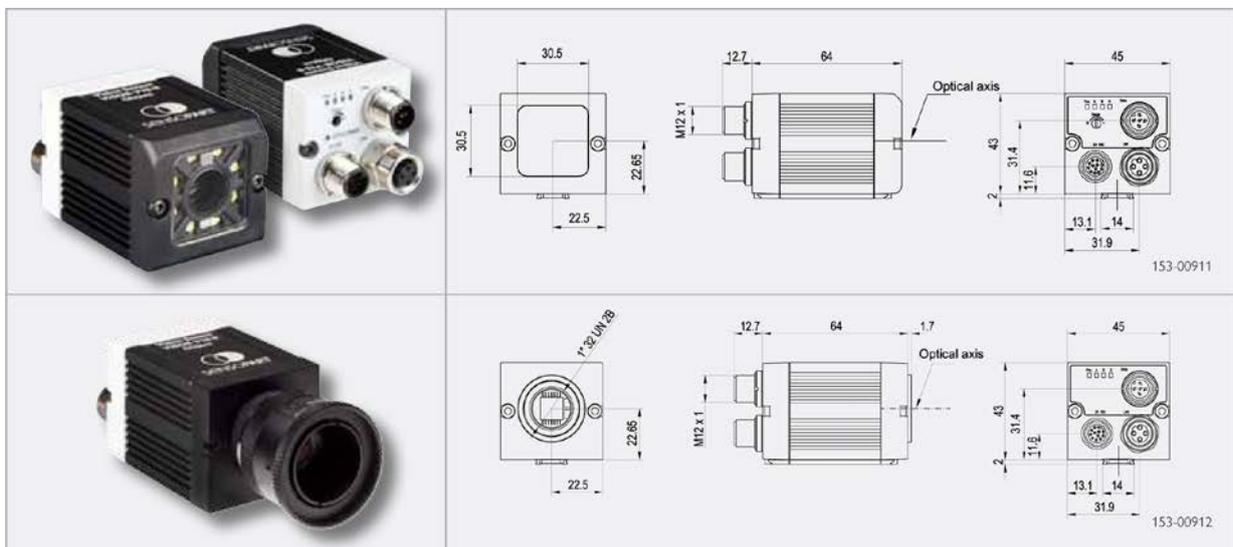


Figure 2: VISOR® drawings

Top: Integrated lens and illumination

Bottom: C-Mount version

### 3.1 Product lines

The *Standard* product line of the VISOR® V10 provides fundamental functions for the detection of wafer position and chips. The complete feature set is provided as *Advanced* product line.

<b>Product line overview</b>	V10-SO-Standard	V10-SO-Advanced
		
<b>Features</b>		
Position accuracy <sup>^</sup>	± 50 µm	± 50 µm
Repeatability <sup>^</sup>	± 1 µm	± 1 µm
Alignment to fiducials	-	✓
Chip detection limit <sup>^</sup>	0.5 mm	0.5 mm
Double layer detection	✓	✓
Busbar position	-	✓
Hole detection	✓	✓
Sunny Side up / down detection	✓	✓
Typical cycle time @wafer (VGA) <sup>^^, ****</sup>	<75 ms	<75 ms
Typical cycle time @cell (VGA) <sup>^^, ****</sup>	-	<150 ms
Number of jobs	2	255
Number of detectors	32	255
<b>Detectors</b>		
Wafer	✓	✓
Busbar	-	✓
Pattern matching	-	✓
Grey level, brightness, contrast	✓	✓
<b>Optics</b>		
Max. Resolution	WVGA = 736x480	WVGA = 736x480
Illumination	White	White or Infrared
Focal length	6 mm	6 mm or 12 mm
Min. working distance for 6" Wafer	350 mm	350 mm, 700 mm
C-Mount	-	Optional
<b>Interfaces</b>		
Number of digital outputs	2	2
Number of inputs	4	4
Number of configurable I/O ports	2	4
Encoder input	-	✓
Ethernet	✓	✓
EtherNet/IP	✓	✓
RS 232, RS 422 <sup>^^^</sup>	-	✓
IP class	IP 67	IP 67 <sup>****</sup>
<b>Stability</b>		
Subsequent tests	>4Mio parts	>4Mio parts

<sup>^</sup> Typical values under recommended conditions, 1 wafer, subsequent measurements, 5 mm travel  
<sup>^^</sup> Typical values, Wafer: Wafer detector only; Cell: Wafer and busbar detector  
<sup>^^^</sup> Cameras manufactured before September 2012 and updated to this firmware show different properties.  
<sup>\*\*\*\*</sup> C-Mount version reaches IP 65 with overhousing

Figure 3: Product line overview of VISOR® Solar

Note: The VISOR® Solar performs both wafer and in cell analysis. For reasons of simplicity in the following only the term 'wafer' will be used representing both kinds of devices: Wafers and cells

### 3.2 Machine integration

#### 3.2.1 VISOR® product line

Within the *Advanced* product line (V10-SO-A...) different models are available to provide the best fit to the requirements of the specific machine. They offer different colours of the internal illumination and different focal length lenses to adapt to the required working distance.

White light cameras are most frequently used and can be combined with external red ring or area lights as well. Infrared light is not seen by the operators, and thus avoids potential disturbances by the flash, and is also very robust against ambient light changes due to its special in built lens filter.

According to the requested working distance the lens type is selected. The table below provides information on typical setups.

Typical dimensions*	V10-SO-S1-W6 V10-SO-A1-W6	V10-SO-A1-W12	V10-SO-A1-I6	V10-SO-A1-I12	V10-SO-A1-C (C-Mount) + 8 mm Lens*****
Product lines	Advanced & Standard	Advanced	Advanced	Advanced	Advanced
Illumination	White	White	Infrared	Infrared	External red ring Light
Internal Lens: Focal length	6 mm	12 mm	6 mm	12 mm	None
Working Distance**	364 mm	712 mm	364 mm	712 mm	536 mm
Shutter speed with reflective foil***	0.17 ms	0.09 ms	0.16 ms	0.06 ms	0.62 ms
Shutter speed with back light****	0.23 ms	0.17 ms	n.a.	n.a.	0.15 ms

\* Field of view: 6" Wafer + min. 10% space  
 \*\* Measured from lower edge of camera to wafer  
 \*\*\* Typical values for wafer detection on RF 775  
 \*\*\*\* Typical values for wafer detection on LF 200 RD  
 \*\*\*\*\* Using LFR 115 RD-24-2L12 and LO C 8

Figure 4: Key parameters of VISOR® V10-SO for machine integration

An easy way to calculate the distance as a function of the field of view is to use the software tool *SensoCalc*, which can be downloaded from our homepage [www.sensopart.com](http://www.sensopart.com), see section "9 Useful links and contacts".

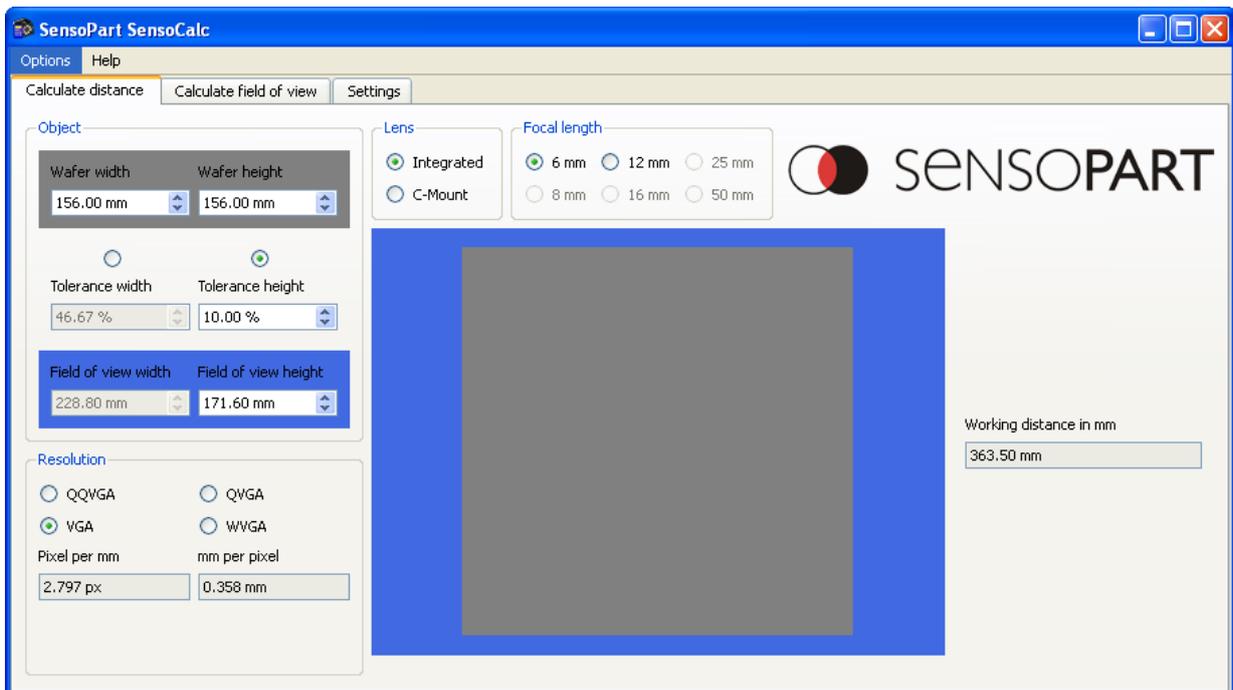


Figure 5: *SensoCalc* supporting the selection of the best fitting camera for a given field of view and working distance

A second criterion to choose the right lens can be the ability to detect chips at the edge of the wafer. Chips can be identified by the two tools *Chip Size* and *Chip Shape*. The ability to detect a chip depends on the size and shape of the defect and to a minor extent on the lens used.

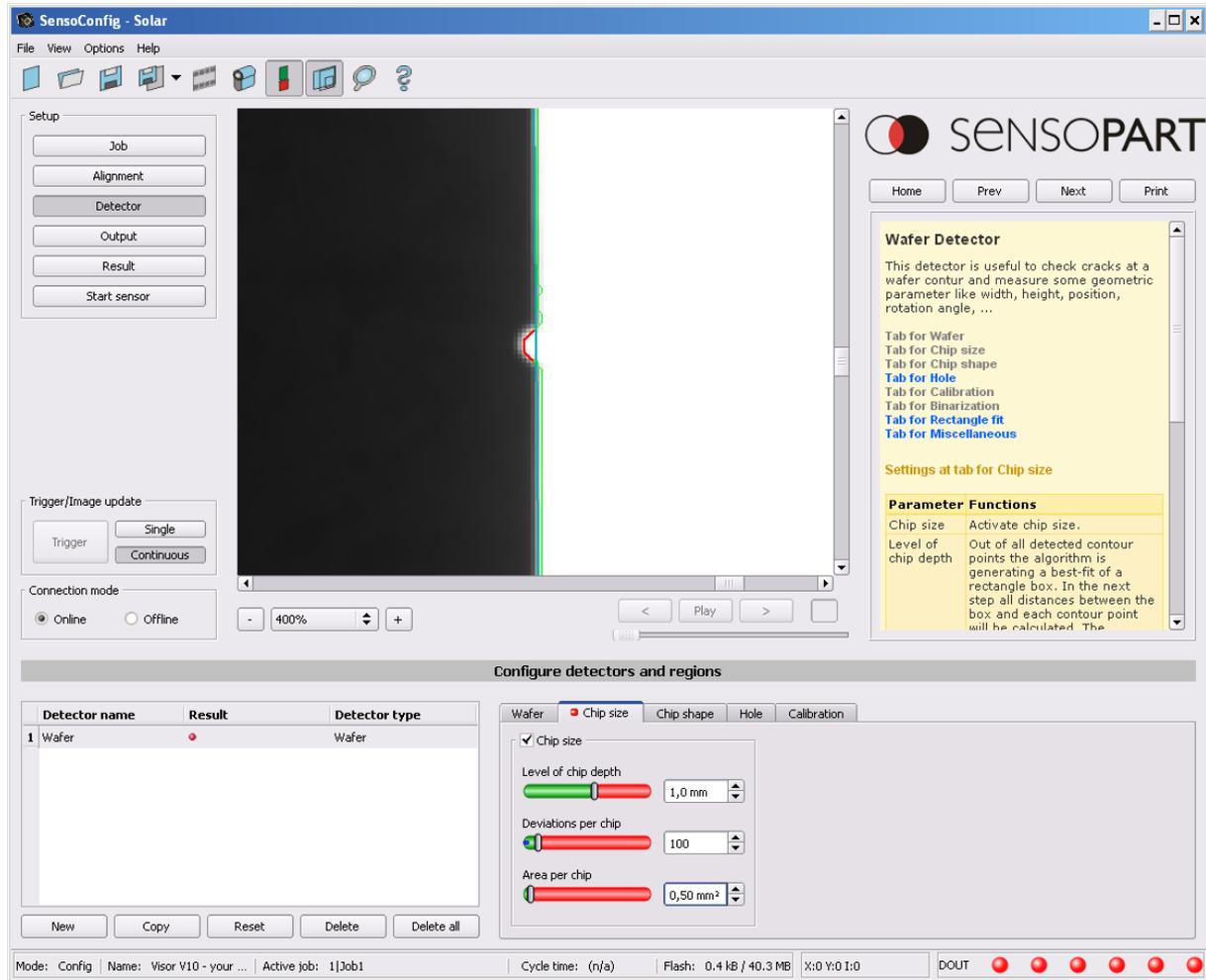


Figure 6: Screenshot when detecting an 1 mm deep chip of a wafer with the “Chip size” tool.

Setup of V10-SO as shown in Figure 1.

The slight dependence of the detection limit on the lens used is described in *Figure 7*. All cameras meet typical requirements using the *chip shape* tool. However, the best results optically are obtained using the 12mm or C-Mount models.

<b>Limits of chip detection</b>	<b>V10 SO 6 mm lens</b>	<b>V10 SO 12 mm lens</b>	<b>V10-SO-A1-C LFR 115 Red, LO C 8</b>
<b>"Chip size" Tool</b>			
Square	1.0 mm	1.0 mm	1.0 mm
Semicircle	1.0 mm	1.0 mm	0.8 mm
Blunt (w/d = 5:1)*	1.0 mm	0.9 mm	0.5 mm
Blunt (w/d = 10:1)*	1.0 mm	0.9 mm	0.6 mm
Triangle 30°	1.2 mm	1.1 mm	1.1 mm
Triangle 60°	1.2 mm	1.1 mm	1.1 mm
Triangle 90°	1.2 mm	0.9 mm	0.9 mm
Triangle 120°	1.0 mm	0.9 mm	0.7 mm
Setting "Level of Chip depth"	0.6 mm	0.6 mm	0.2 mm
<b>"Chip shape" Tool</b>			
Square	0.6 mm	0.5 mm	0.6 mm
Semicircle	0.5 mm	0.5 mm	0.5 mm
Blunt (w/d = 5:1)*	0.4 mm	0.4 mm	0.4 mm
Blunt (w/d = 10:1)*	n.a.	n.a.	n.a.
Triangle 30°	1.2 mm	1.0 mm	0.8 mm
Triangle 60°	0.7 mm	0.7 mm	0.7 mm
Triangle 90°	0.6 mm	0.5 mm	0.5 mm
Triangle 120°	0.6 mm	0.5 mm	0.5 mm
Setting "Angle deviation"	15°	15°	15°
*w/d = Width / Depth			

Figure 7: Typical limits of chip detection

### 3.2.2 Illumination & Background

For sufficient robustness against ambient light and vibrations a shutter speed below 1 ms should be used. The wafer and cell can be illuminated by the camera internal LEDs or by adding a ring light such as with the red ring light LFR 115 RD-24-2L12. In cases where it is difficult to reach a sufficient shutter speed, a ring light can be used in parallel to the internal light. Since C-Mount cameras are not equipped with internal LEDs, a ring light becomes mandatory.

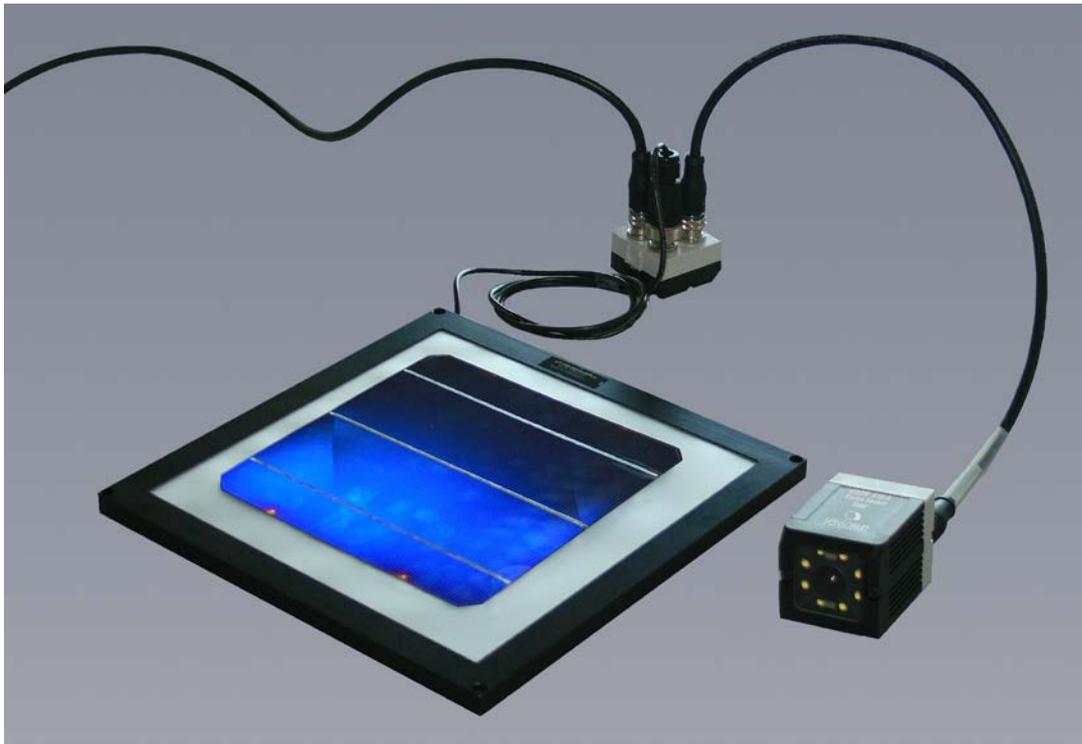


Figure 8: V10-SO-A1-C with C-Mount lens and ring light LFR 115 RD-24-2L12

### 3.2.2.1 Illumination & Background for wafer analysis

For wafer analysis it is recommended to place the reflective foil RF 775 in the background. Using integrated powerful illumination, this results in a shutter speed of less than 0.2 ms for very little costs. A similar approach can be followed using the C-Mount camera with a ring light. For detailed values of the shutter speed see *Figure 4*.

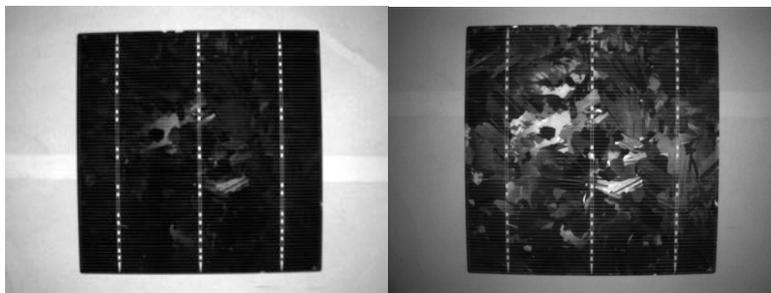
In the special case of detecting holes in wafers or cells a back light is necessary to provide sufficient light through the tiny defects. Such backlight lights can be controlled by the sensor when adding the connection adapter LA 45 V-24-2L12.



**Figure 9: VISOR® with Back light LF 200 RD and connection adapter LA 45 V-24-2L12**

### 3.2.2.2 Illumination & Background for cell analysis

To analyse the printing on the front side of a cell, Infrared illumination is strongly recommended. The usage of white illumination may cause disturbing reflections in combination with polycrystalline material.



**Figure 10: Images of a polycrystalline cell with poor antireflective coating using recommended infrared (left) and non-recommended white illumination (right)**

As background the usage of a homogeneous white material is recommended. This can be plastic or coated aluminium. Do not use the reflective foil in these applications.

### 3.2.3 Mounting accessories

Each VISOR® camera comes with a mounting clamp MK 45. The camera may be fixed to it via the dovetail fitting on its base.

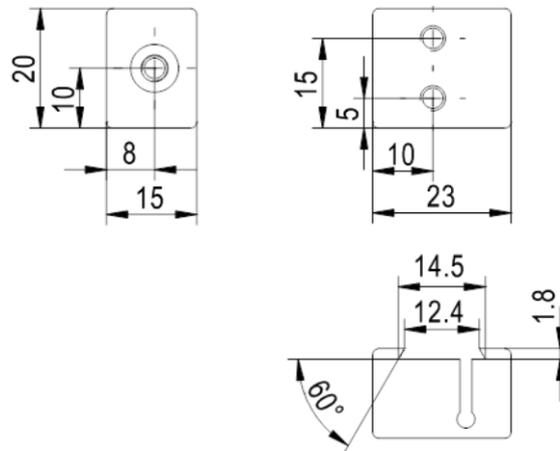


Figure 11: Mounting clamp MK 45

To support the easy and precise adjustment of the camera, the use of the mounting bracket MG 2A (no. 543-11023), shown in "Figure 12: Mounting bracket with two axes MG 2A" is recommended. The precise orientation of the camera towards the object is crucial for reliable measurements.

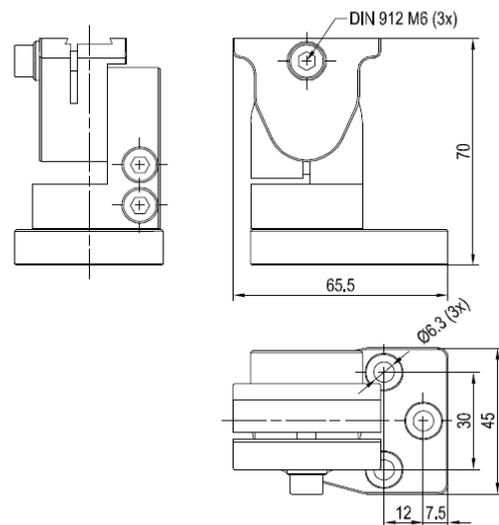


Figure 12: Mounting bracket with two axes MG 2A

Mounting kits are available for the accessories like external illumination as well and can be found using the product finder on the SensoPart homepage, [www.sensopart.com](http://www.sensopart.com) see section "9 Useful links and contacts". Within the VISOR product family the different accessories may be combined, e.g. an MG2A with external illumination.

## 4 Setting-up the camera

### 4.1. Installation

The *VISOR*® user manual provides detailed information on the setup. The document can be found under Windows Start / All Programs / SensoPart / VISOR vision sensor / Documentation. In this document the main steps are briefly listed.

- Mechanical mounting the clamp and the camera
- Electrical connection to power supply and Ethernet, optionally to PLC and trigger input
- Assign IP address to the camera
- Adjust the focus screw for a sharp image
- Configure a camera job or upload a job file to the camera
- Verify image quality and output results

After just about 15 minutes of mounting and installation, the sensor runs autonomously within the machine performing the desired wafer tests.

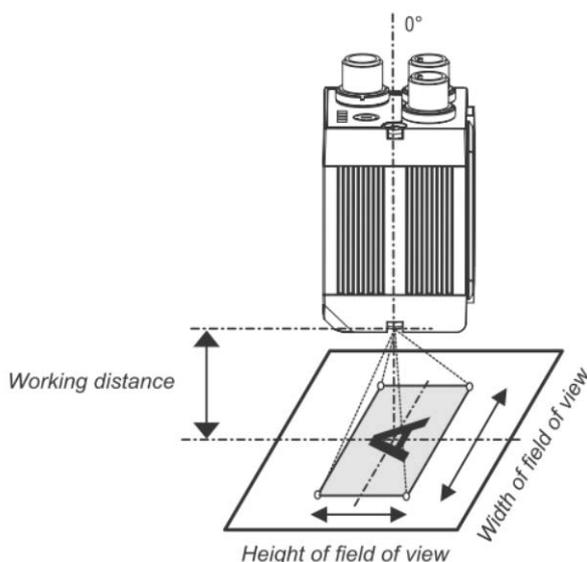
#### 4.1.1 Mechanical mounting the clamp and the camera

**At first, the mechanical mounting is done. The camera should be mounted at a location with minimal vibration, perpendicularly to the wafer respectively cell and with free line of sight to it. Usually, the mounting bracket *MG 2A* is used supporting easy adjustments. Alternatively, a precisely adjusted mounting clamp *MK 45* may be used.**

The camera should be mounted on a stable part of your machine with the correct working distance, which is depending on the camera-type (see section "3.2.1 VISOR® product line") from your wafer respectively cell. The mounting bracket *MG 2A* is fixed with three cylinder head M6 screws in the base plate. To assemble the mounting clamp *MK 45* on your machine use the two internal screw threads (both M4) on the back side of the clamp. The mounting bracket *MG 2A* is fixed with three M6 screws in the base plate.

The camera can be fixed on both mounting accessories with the dovetail on the front side. Before mounting the camera make sure, that is possible to route all cables needed in a proper way to the camera. This is simplified by our offered cables with the optional angled plug. Make sure that under every operation condition no parts disturb the sight of the camera towards the wafer / cell.

The targeted mounting situation is shown here:



**Figure 13: The mounting situation**

The precise adjustment can be done when the camera is working with your PC and will be described later.

#### 4.1.2 Electrical connection

After mechanical mounting, the electrical connection is built up. On top of the camera there are three connection sockets (see *Figure 2*). The 24 VDC connection socket provides the power supply and digital I/O of the camera. Use a cable CL12FX-Xm (available in 2m, 5m, 10m with angled or straight plug) to connect the power supply of the camera and the I/O with your PLC. The pinning of the cable is shown in the following table:

PIN	Colour of wire	Usage
1	Brown	+ Ub (24V DC)
2	Blue	GND
3	White	IN (external trigger)
4	Green	READY <sup>1</sup>
5 <sup>2</sup>	Pink	IN/OUT ( <i>Advanced</i> version: encoder -)
6 <sup>2</sup>	Yellow	IN/OUT
7 <sup>2</sup>	Black	IN/OUT, LED B
8 <sup>2</sup>	Grey	IN/OUT, LED C
9	Red	OUT (external illumination)
10	Violet	IN ( <i>Advanced</i> version: encoder +)
11	Grey & Pink	VALID <sup>3</sup>
12	Red & Blue	OUT (ejector, max. 100 mA), LED A

<sup>1</sup> READY: Ready for next external trigger

<sup>2</sup> Switchable input/output

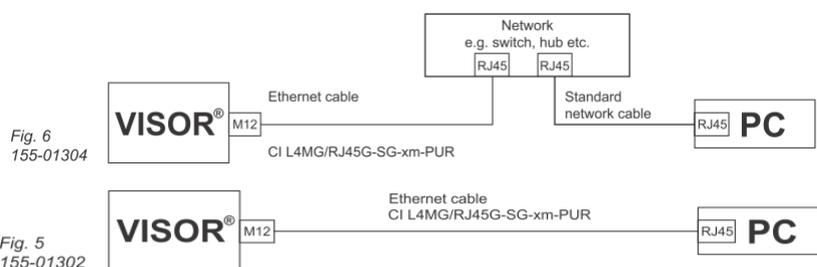
<sup>3</sup> VALID: Indicates that the image analysis has been done and the outputs are set according to the result.

**Figure 14: Pinning of the power supply and I/O cable**

The I/Os on pins 5-8 provides currents of max. 50 mA each.

For detailed information of the electrical characteristics see *VISOR® user manual* as well.

Now use the "LAN" socket to connect the camera via Ethernet to your PC or PLC, the required cables are named CI L4MG/RJ45G-SG-Xm-PUR (available in 3m, 5m, 10m with angled or straight plug). To configure the sensor you need to setup a connection to a PC. After the configuration, no PC is needed and the sensor will work as a stand-alone system. It is possible to connect the PC directly to the camera or via a switch or hub as shown here:



**Figure 15: Possible Ethernet interfacing of the camera**

In the *Advanced* version of the camera, the *Data* socket may be used for serial data transfer to a PLC. For connection use a data cable like CI L5FS Xm-G/W-PUR with the RJ45 connector (available in 2m, 5m, 10m with angled or straight plug).

After connection of all needed cables switch on the power supply and check the LED display of your camera. The correct connection of the power cable results in the lighting of the green *Pwr* LED. After connection, the camera will flash once to indicate it has finished the power up and is ready for operation.

#### 4.1.3 Assign IP address to the camera

After the electrical connection is done, the camera has to be linked to your PC. To connect the VISOR® Vision Sensor to a PC via ethernet the IP addresses of both devices have to correspond. PC's ethernet socket (not WLAN) and sensor have to be in the same subnet, but have different IP numbers. That means their IP addresses are identical except of the number behind the last dot.

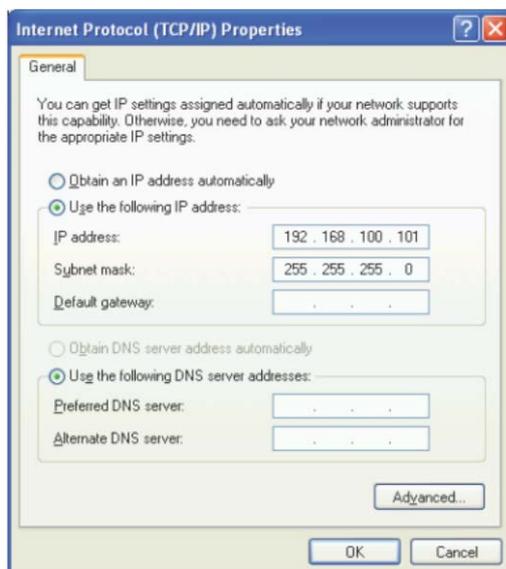
The default IP of the VISOR® is 192.168.100.100 with Subnet mask = 255.255.255.0. To establish a direct connection, e.g. the PC must be set to a corresponding, fixed IP address like follows. Alternatively, the sensor's IP address has to be changed.

*The following settings are described for operating system Windows®:*

1. Click on Start → Control Panel → Network Connection → LAN Connection → Properties → the window "Local Area Connection Properties" is open.
2. In the list „This connection requires following elements“ select the option „Internet Protocol (TCP/IP)“ and then click the button „Properties“.
3. In the following window (see fig. 15) set the desired IP address of the PC and the sub-network data.
4. Confirm entries with OK

Example:

The VISOR® Vision Sensor is pre-set to IP address 192.168.100.100 and subnet mask 255.255.255.0. In this case, the IP address may be set to any value between 192.168.100.1 and 192.168.100.254, with subnet mask 255.255.255.0, with the exception of existing IP addresses like the one of the PC used.



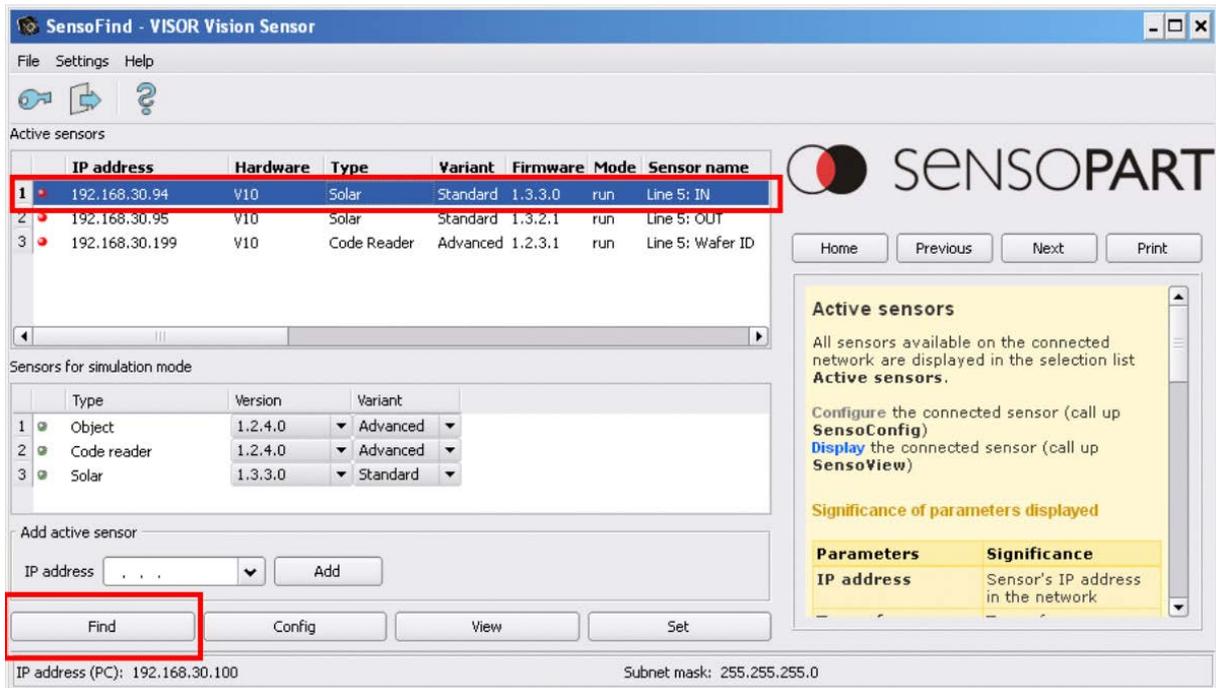
**Figure 16: IP properties**

To change the IP address of the sensor, see use button "Set" of the program SensoFind being described in the next section.

#### 4.1.4 Starting up the Software *SensoFind*

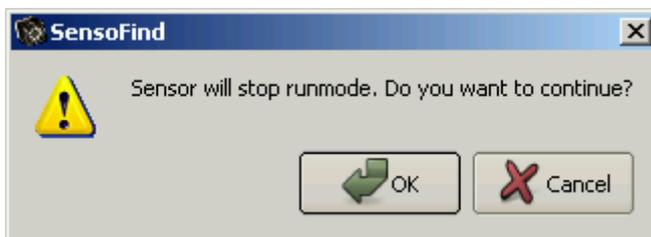
Now most (excluding the fine adjustment and the focusing) of the “Hardware” configuration steps are done and the remaining steps of the configuration of your sensor will be done with the programs *SensoFind* and *SensoConfig*. With the next steps, the fine adjustment of the sensor will be checked and the conditions to ensure best possible imaging conditions will be prepared.

First start the program *SensoFind*. In the first opened window, all connected cameras will appear in the ‘Active sensor’ list. If no camera appears, click on the button ‘Find’ on the left (see *Figure 17*). When there is also no camera available or a connection is not possible, this is likely due to incompatible network and firewall settings on the local PC. In this case please contact your local IT department to solve the issue.



**Figure 17:** *SensoFind* is used for the camera selection, here are 3 cameras found (2 solar + 1 code reader)

Double-click on the sensor to start the program *SensoConfig*. Automatically a small window (*Figure 18*) will open. If you press “OK”, the sensor will stop working, therefore, you should not do this while the sensor and the machine is working. It may cause damage, depending on your machine configuration. After ensuring your machine and sensor are in a safe operating mode press OK to continue.



**Figure 18:** Warning Pop-up

Afterwards a window like this will be shown:

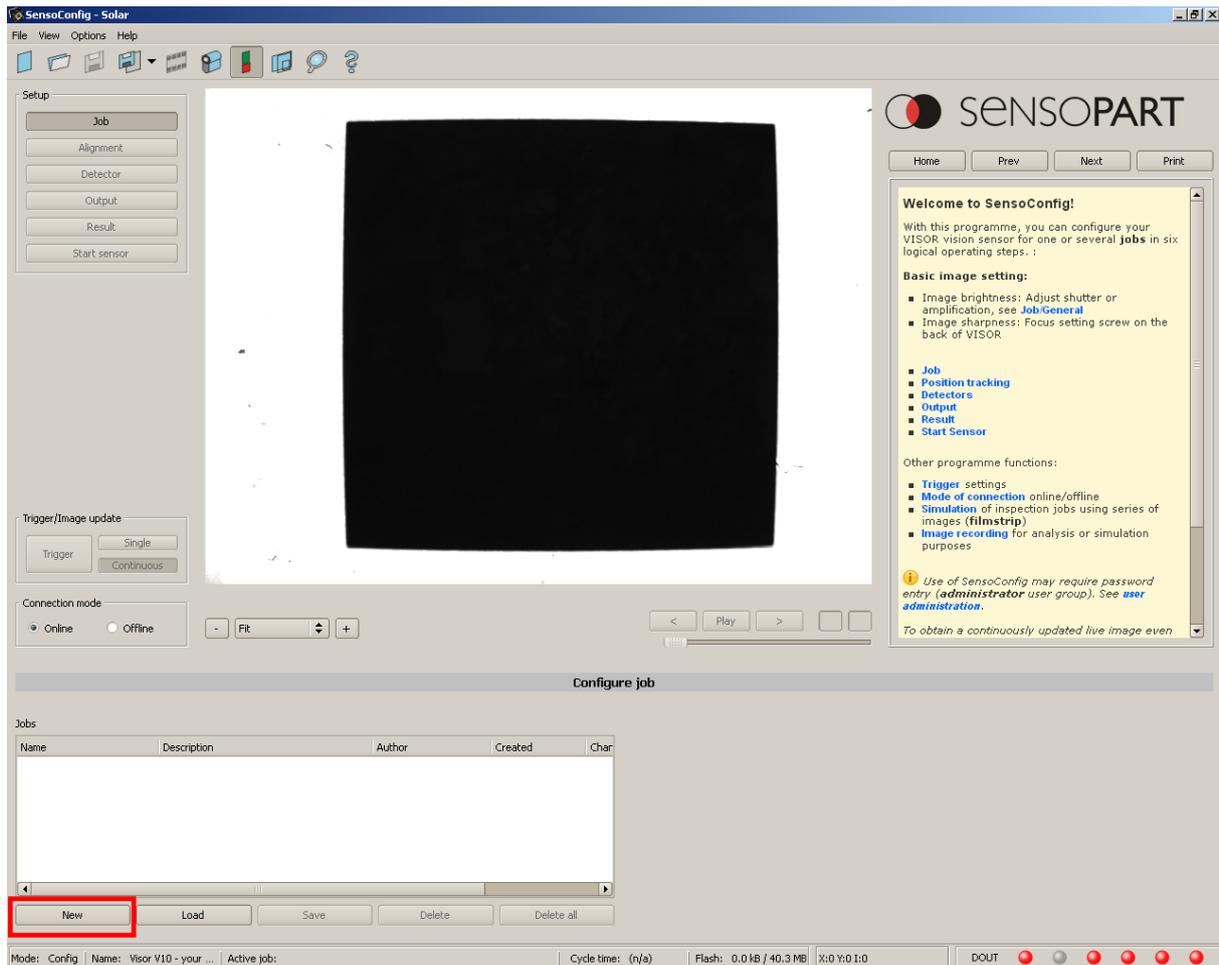


Figure 19: Screenshot of an *SensoConfig* window with a wafer image

Press the „New“ button (marked with the red rectangle in *Figure 19*), this will create you a new default “Job” and allows you to make the necessary settings (e.g. the shutter speed). A detailed description of transferring the “Job” is given in section “4.1.7 Configure or upload a job file to the camera”

You are now able to configure the sensor and make the necessary settings.

#### 4.1.5 Adjust the sensor to ensure the perpendicular mounting

First check if the sensor is mounted in the right working distance. The working distance can be calculated with the program *SensoCalc*. For further information refer to section 3.2.1 *VISOR® product line*.

First adjustments target the perpendicular mounting of the sensors to the wafer or cell to be checked. Use a reflective foil, mirror or sheet of glass and put it on the position your wafer is typically placed. Other positions (e.g. an direction of view not perpendicular to the object) can cause a maladjustment. You get an image from your sensor like this:

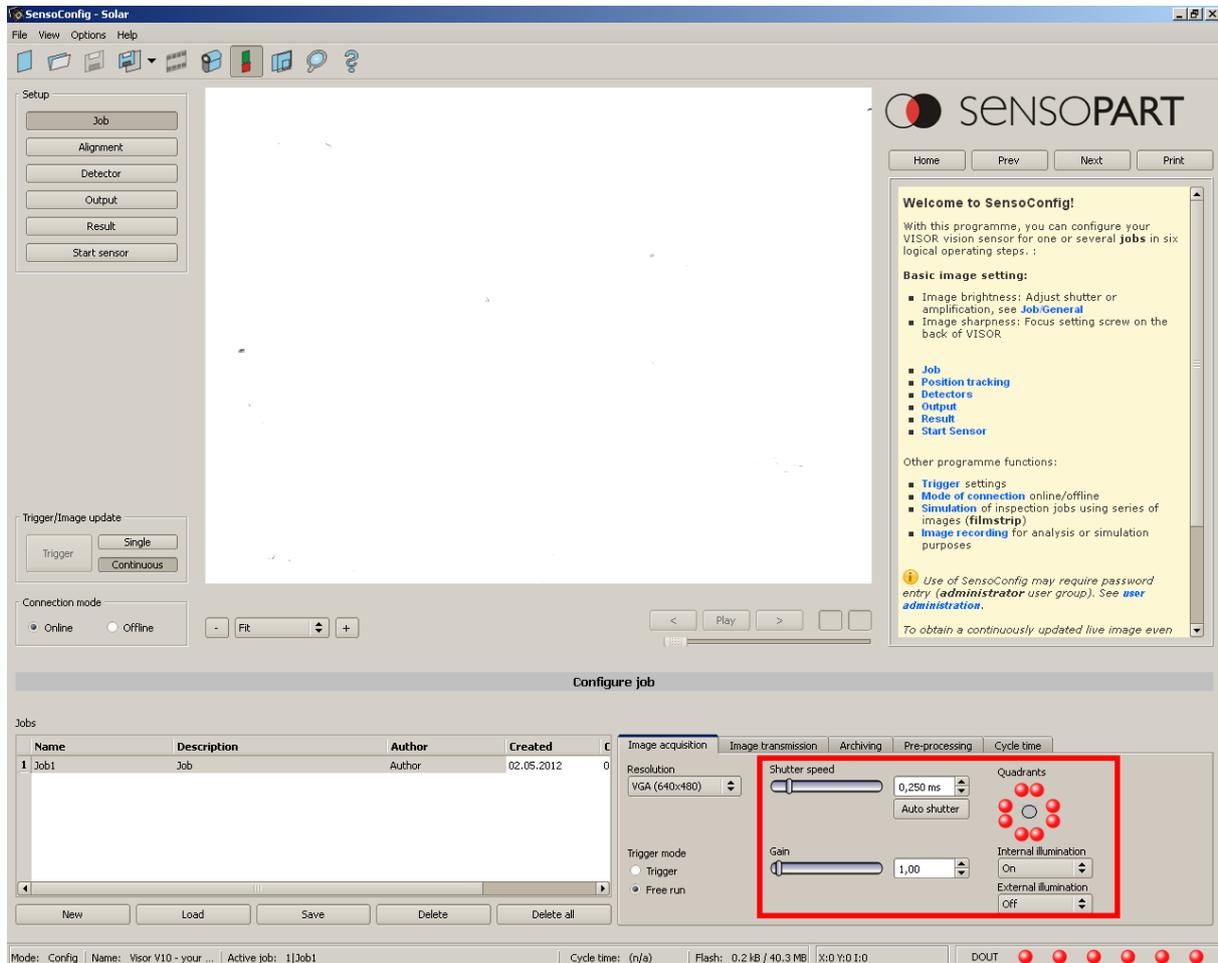
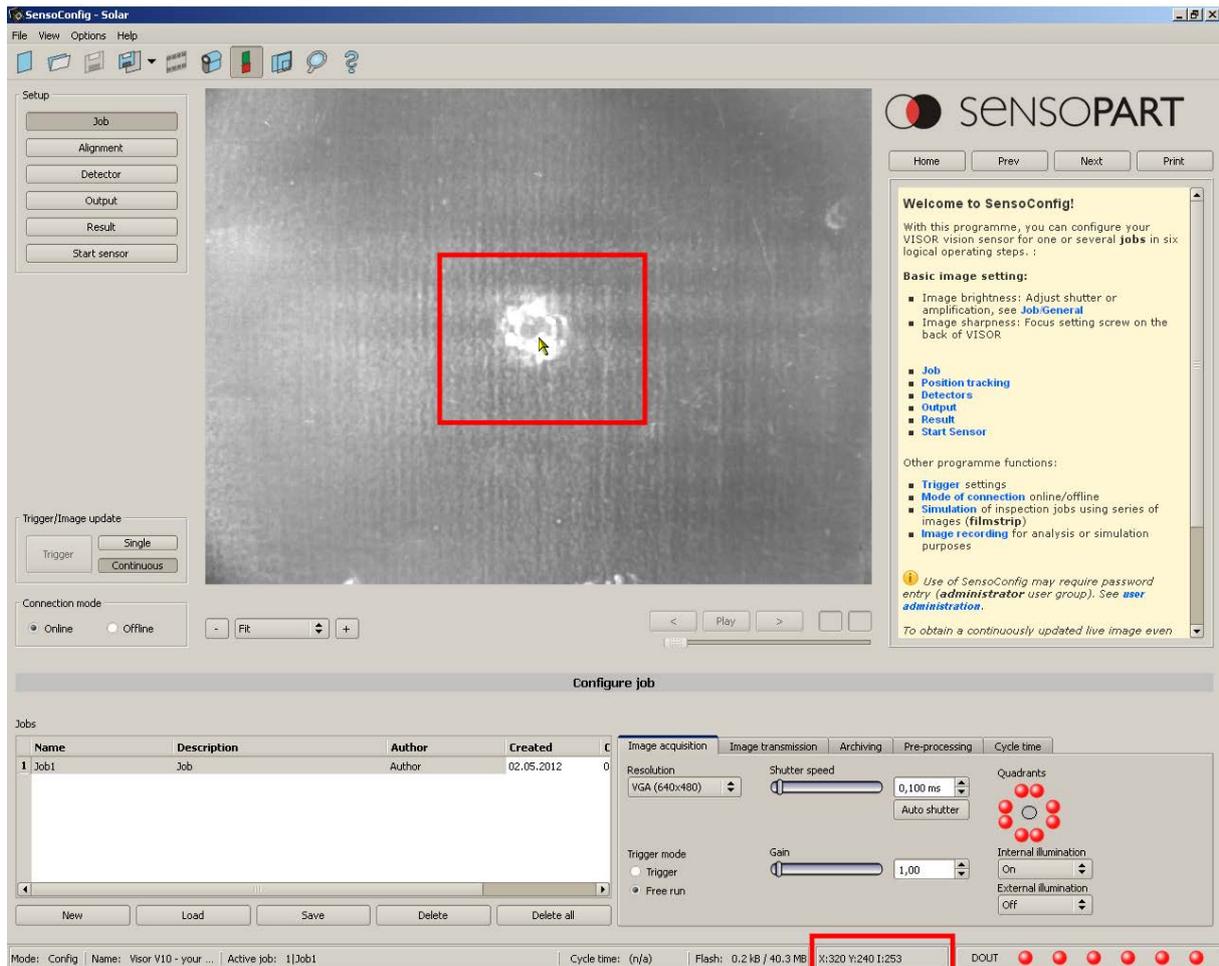


Figure 20: Camera image of the reflective foil

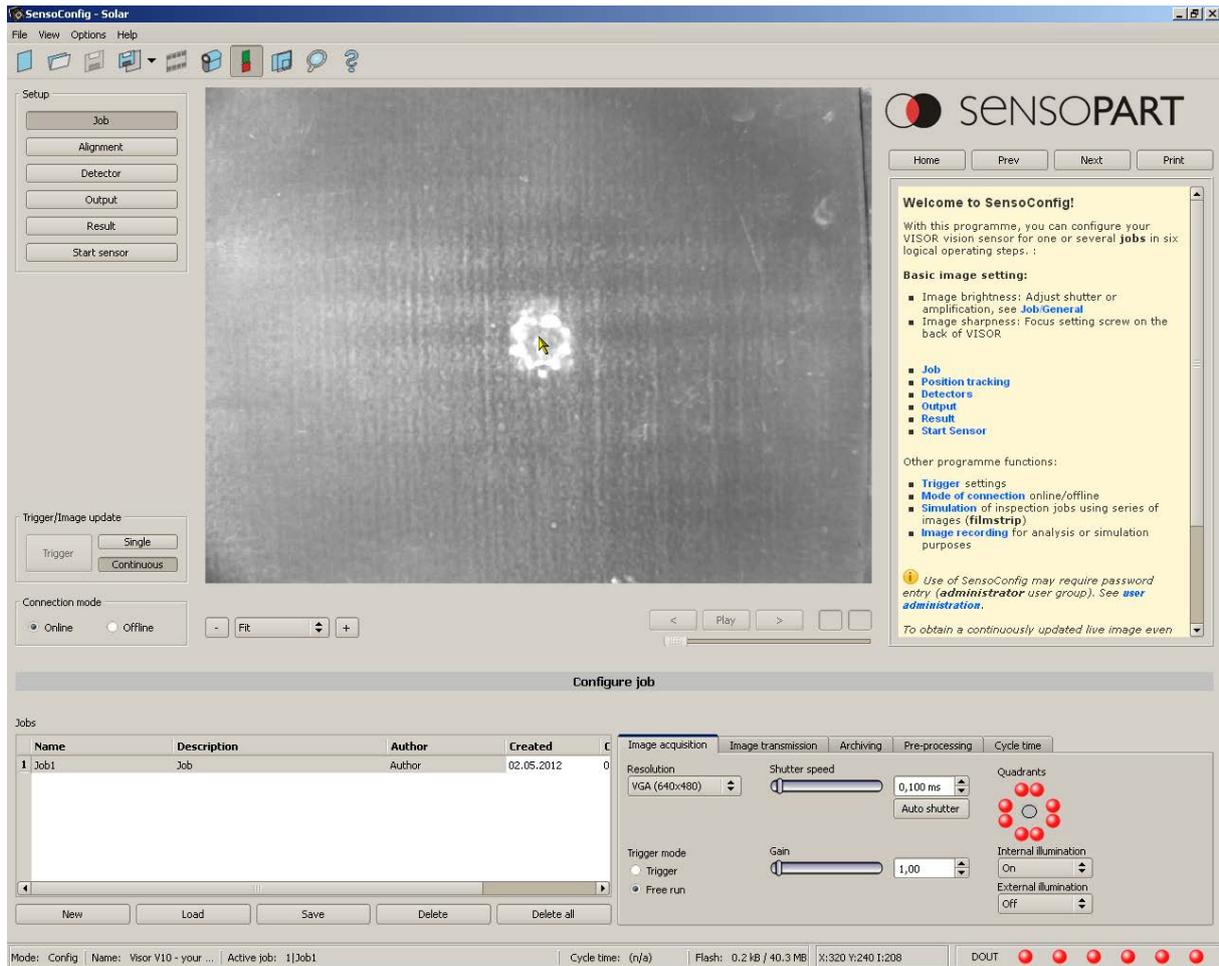
Decrease the *shutter speed* (use the slider or the spin box marked with a rectangle in *Figure 20*) to get an image with a bright dot / ring of bright dots near to the centre and a dark background:



**Figure 21: Camera image of a reflective foil with the cursor position marked**

The position of the bright spot should be in the centre of your camera image. To ensure this, the best method is the following:

- Bring the cursor to the position of the half resolution of your camera, e.g. for VGA X: 320, Y: 240. The current position of your cursor is indicated on the bottom of the window in pixels. In *Figure 21* above it is marked with the lower rectangle, in the same part of your window the intensity I at the cursor position is printed as well.
- Then, adjust the sensor mechanically to move the centre of the bright spot into the centre of the field of view (which is marked with your cursor now). Then your image should look like *Figure 22*.

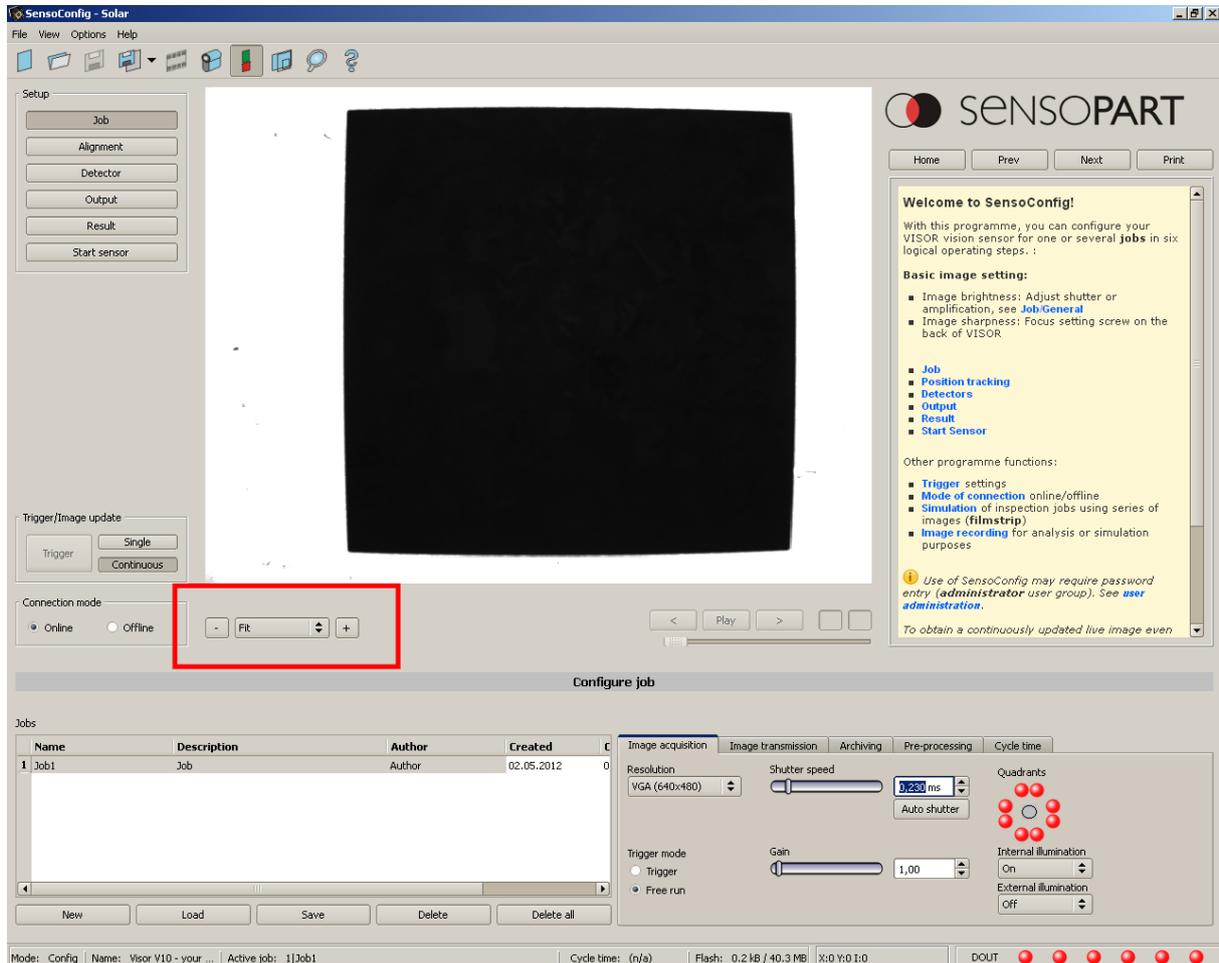


**Figure 22: Camera image with the correct perpendicular mounting of the sensor image**

Now you can be sure your sensor is properly adjusted. You are now able to check the focus.

#### 4.1.6 Focusing

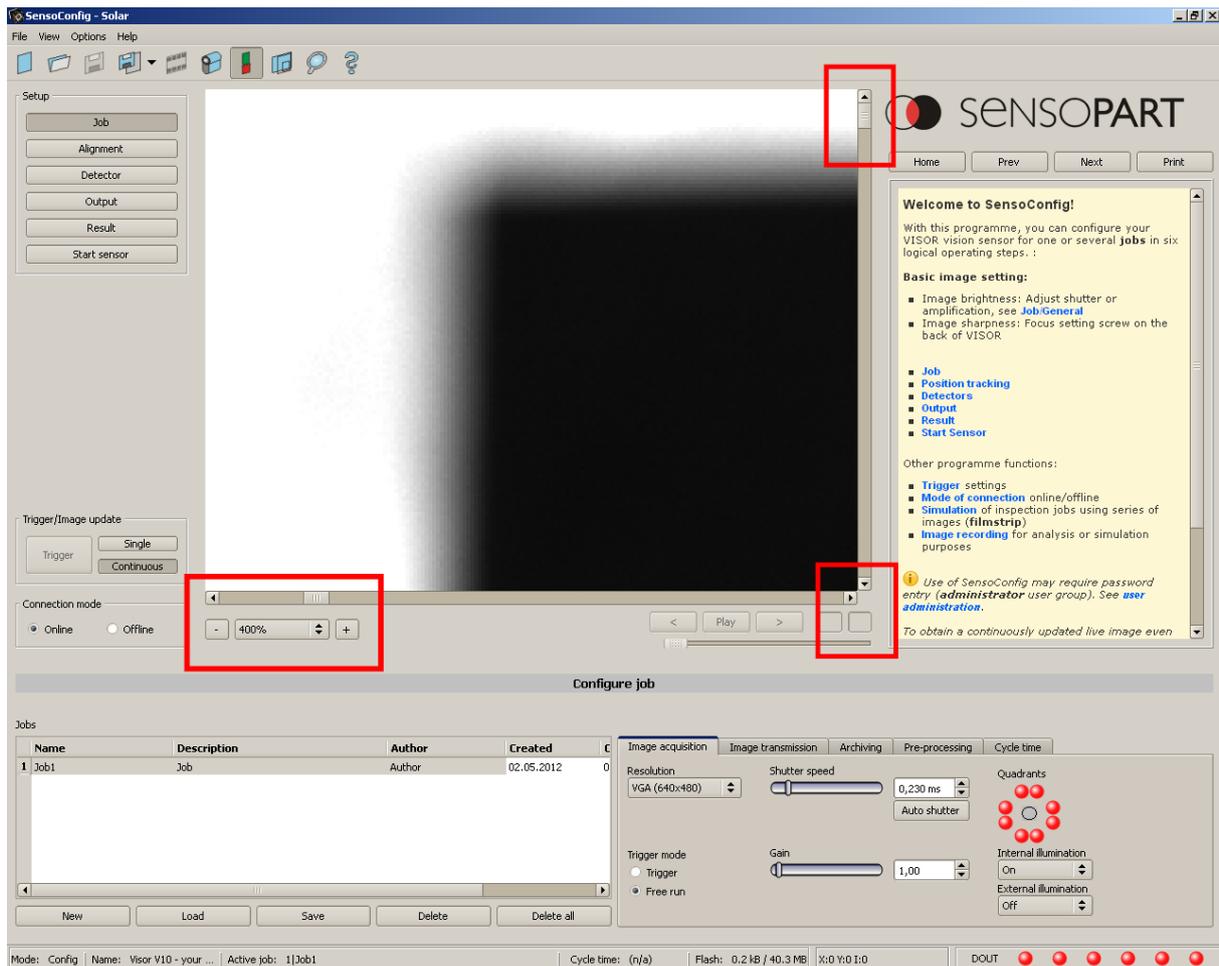
Place a wafer under the sensor and increase the shutter speed from low values until you reach an intensity of 255 on the complete reflective foil. Your screen should look like *Figure 23*.



**Figure 23: Camera image with the right working distance and optimal mounting**

Then zoom in (use the controls marked with a rectangle in *Figure 23*) to see an enlarged image of the upper left corner of the wafer.

To scroll the image use the scroll bars marked in *Figure 24*.



**Figure 24:** Camera image with the marked scroll bar

Use the screwdriver supplied (others may cause damage) to rotate the small slotted screw "focus" in the rear of the camera and ensure a sharp image of your wafer. The sharper the image focus, the more accurate the camera will perform chip measurements and surface analysis. Ideally, the transition from dark to light is completed within 2-3 pixels (cells on the image chip).

After getting a sharp image of the first corner scroll to the other corners and ensure they are sharp as well. Maybe, the focus needs to be readjusted to get the most sharp image of the complete wafer. A sharp image looks like this:

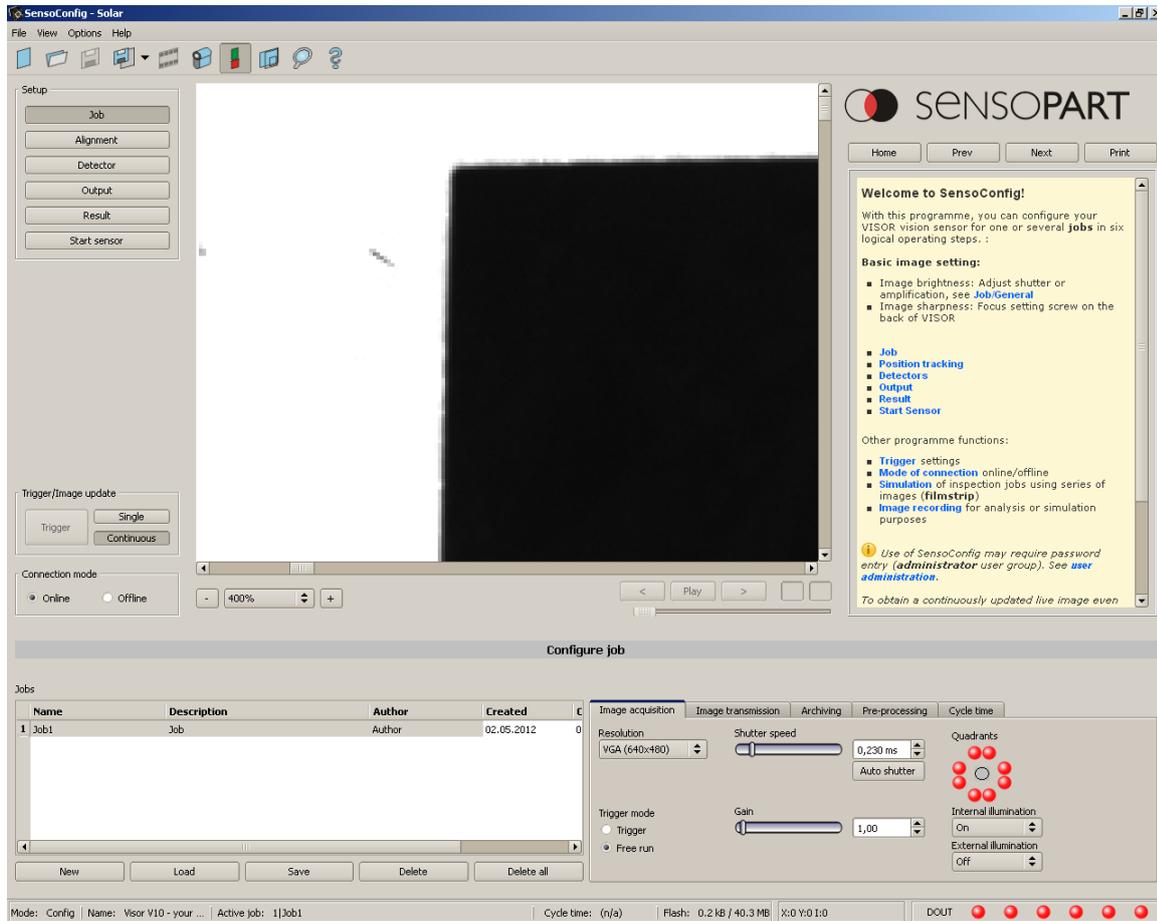


Figure 25: Sharp image of an wafer

Now, all sensor adjustments are completed and the mounting of the sensor is finished. The adjustments and settings done should not be changed, readjustments are usually not needed.

#### 4.1.7 Configure or upload a job file to the camera

The sensor works with instructions saved in the "Job" File on a PC drive. The *Job*-file contains all settings previously defined using the *SensoConfig*-Software. Each *Job*-file can be uploaded to the sensor for stand-alone operation. There are three principle ways to get a job file:

- Create a new job as described in section "5 Software configuration".
- Load an old job file from your PC which is set up for a machine with the same configuration. To do this click on the "Load" button on the lower and use a saved *Job*-file
- Connect a camera to a PC, start *SensoConfig* and all jobs will be downloaded from the camera to the PC.

To upload a new *Job* to the sensor click on the "Start sensor" button on the upper left side of your window. The sensor will start then to work without the need of a PC, all needed information of the job file are saved on the sensor and will stay there even when the sensor is without a power supply.

The sensors of the *Standard* product line may store up to 2 job files simultaneously. For sensors of the *Advanced* product line the number of jobs may reach up to 255, but may be lower in case of complex jobs.

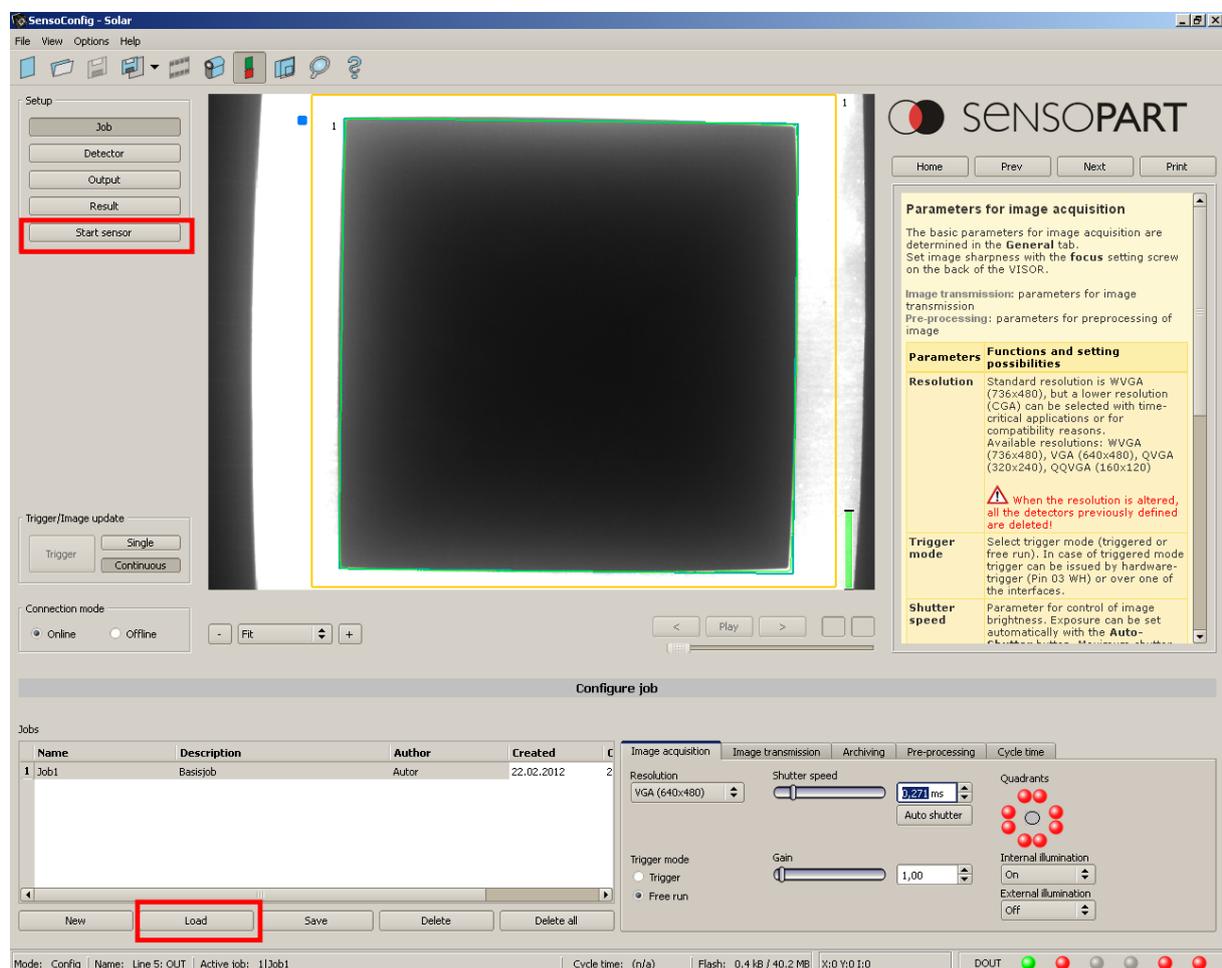


Figure 26: Load a job file and upload it to the sensor.

## 4.2. System design

For best performance during operation the application of the sensor should aim the following targets:

- High precision
  - High accuracy
  - High repeatability and reproducibility
- High robustness against ambient influences, such as
  - Ambient illumination and sun light
  - Vibrations
- Minimal maintenance
  - No re-calibration
  - Sporadic cleaning

In the following these targets are discussed with respect to the different options of setups.

The VISOR® Solar sensor utilises powerful and intensively field-proven algorithms. To ensure that the sensor achieves this standard, some basic aspects of the system design impacting the fundamental camera's image quality need to be discussed. The following sections are useful to make sure the sensor will operate in an optimal way and is able to fulfil its targets.

### 4.2.1 Recommended setup: Reflective foil or back light

High precision and robustness require a short exposure time which is a key success factor as mentioned previously. Preferably this is obtained when analysing wafers by using the VISOR® camera in a setup with a reflective foil RF775 as shown in *Figure 1*. To achieve minimal maintenance and to prevent fragments from accumulating on the foil, it can be tilted to let fragments slide down. Technically and commercially this setup is the most preferred solution.

The reflective foil can be placed freely under the wafer:

- The wafer may lay on top of the foil.
- The foil may be tilted towards the wafer plane.
- When measuring wafers on conveyor belts, the foil typically may be placed several centimetres below the belts, fully supporting accurate measurements.

For the analysis of the front side printing of cells do not use a reflective foil, but a homogeneous white background.

In all setups using the reflective foil, a backlight or a white background, the wafer appears as dark and the background appears as bright.

### 4.2.2 Machine parts in the image

In the absence of an even and homogeneous background, e.g. a reflective foil or a back light, machine parts may be observed by the camera which will affect the analysis of the wafer. Typical examples are conveyor belts being used to transport the wafer and which may be interpreted as chips or protrusions.

To avoid these effects, there are the following software solutions:

- Blanking region feature found in *Detector / Wafer tab / Blanking region*: The conveyor belt can be masked out not to influence the wafer analysis. An example is shown in *Figure 27* below. Blanking should be used to a minimum extend only not to impede the accuracy and processing speed.
- *Ignore protrusions*, which is offered in the *Chip size* tool during *Expert mode*. This way external defects are cut off and not considered. Note: The *Chip shape* tool always ignores protrusions.
- Metals transport belts in the background: *Wafer / Miscellaneous / Contour smoothing* and *Ignore protrusions* provide a reliable analysis in *Expert mode* as shown in *Figure 28*.

Other solutions include:

- Use the different camera lights (SensoPart offers white, red and infrared illumination) to benefit from the different reflectivity of the different materials.
- Try to use dark parts like anodized aluminium or black painted machine parts in the observed section of the machine.
- Reflections of machine parts can be reduced by increasing their distance to the wafer and camera.

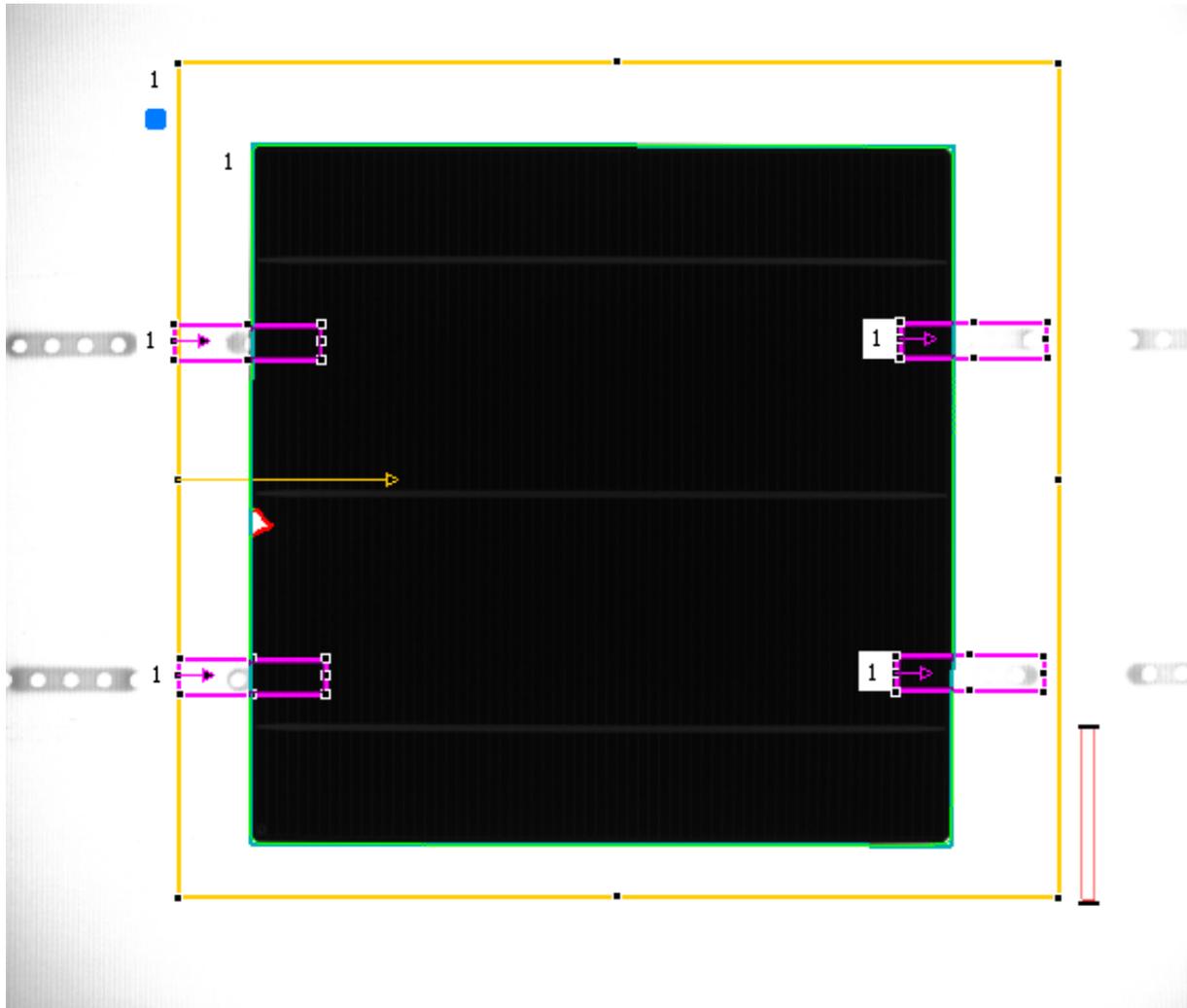
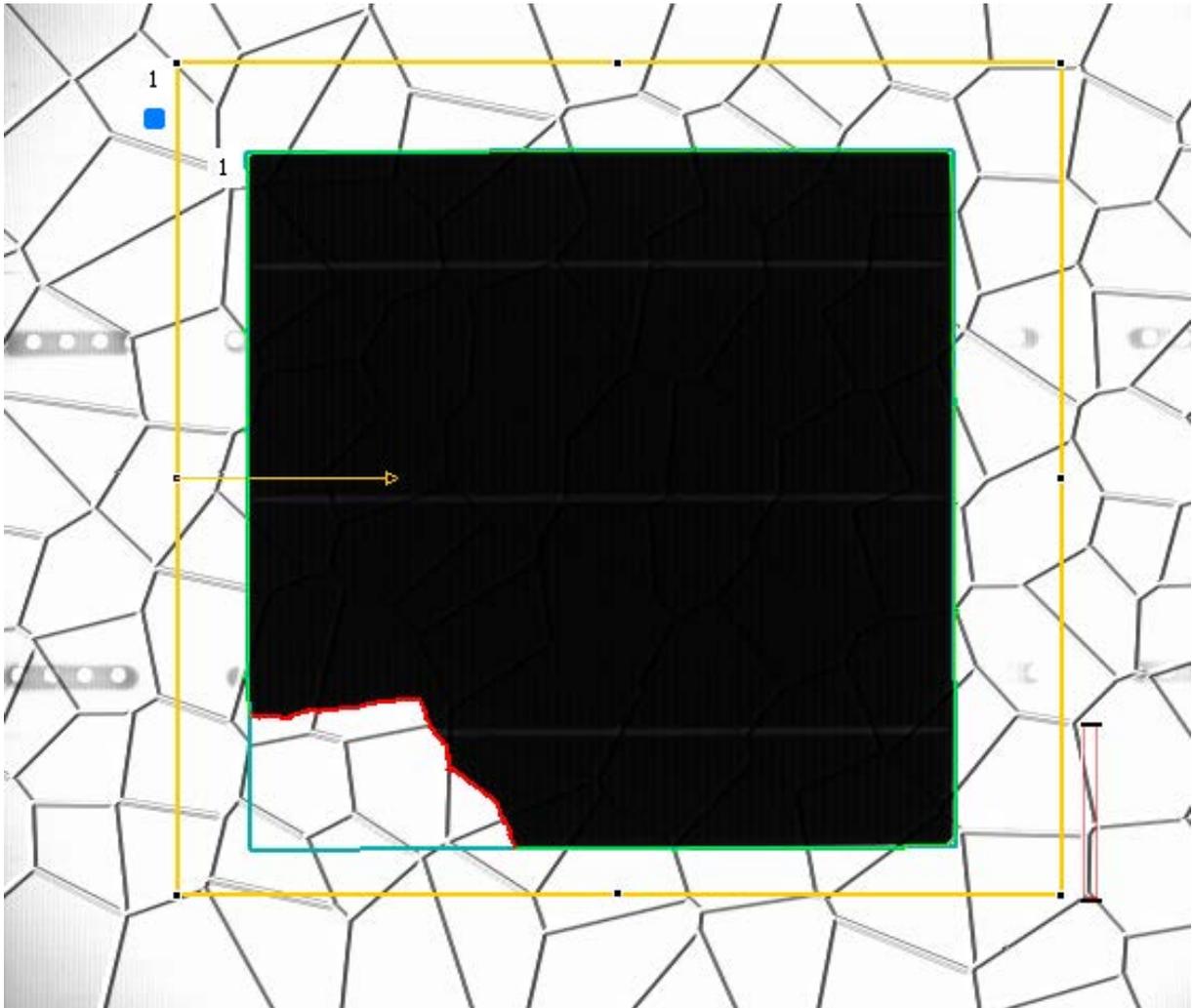


Figure 27: Four purple *Blanking regions* are used to blank conveyor belts: The chip on the left edge is detected without any influence of the conveyor.



**Figure 28:** Using *Contour smoothing* and *Ignore protrusions* the wafer analysis can be performed even on a metal grid.

These examples illustrate the ability of the camera to operate even with confusing and difficult background conditions. Further options for unusual conditions have been established and can be applied in cooperation the SensoPart technical support team contactable at our headquarters in Germany +49 7665 94769-750 or via your local area sales channel.

#### 4.2.3 Front light applications

In case neither a reflector nor a back light can be deployed in the machine, the wafer will likely appear bright in front of a dark background of the machine. This is a satisfactory solution although limitations will be found on the sensors ability to find small defects. It should be noted that for hole detection a back light solution is always required to achieve good image contrast between the wafer and the background. Care and attention has to be spent on shutter speed and contrast, which are treated in the following sections.

#### 4.2.3.1 Shutter speed

The shutter speed has to be adjusted to show the bright parts of the image – either the background or the wafer / cell – with intensity values slightly below saturation.

Since the reflectivity of the reflective foil (RF775) is very high, in this case the shutter speed becomes very short and results in fractions of a millisecond.

Even in case the reflective foil cannot be used, the shutter speed of 1-2 ms should not be exceeded to avoid disturbances by ambient light and by vibrations.

Obviously, the reflectivity of a wafer strongly depends on the process step of the wafer under test. As-cut wafers reflect better than textured ones. The later reflect better than anti-reflective coated cells.

To ensure sufficient shutter speed under all circumstances the user may choose among the following options:

- Increase the overall 'gain' setting for the image up to a value of 4. This can be done in *Job / Image acquisition tab / gain*. Then, the shutter speed can be adjusted by the same factor (see also "Figure 20: Camera image of the reflective foil")
- In case the shutter speed exceeds 1.6 ms the LED power is reduced proportionally to avoid overheating. Adjusting the minimum cycle time of the overall inspection will avoid this. This setting can be found in *Job / Cycle time tab / Cycle time (min)* this effect can be avoided. For details see the online help file in the VISOR software.
- Use an additional ring light in parallel to the internal illumination. This typically reduces the exposure time by a reduction factor of x3 in case of a red ring light. Adding an infrared ring light to an infrared camera provides a reduction factor of x4 in shutter speed.
- Use a C-Mount version with lenses having high aperture

The adjustment of an optimal shutter speed leads to following intensity characteristics:

*Usually the wafer cell is darker than the background (this is the common setting for detection of cells and textured wafers):*

- Intensity on the background near the wafer (e.g. on a reflective foil) should be on 255 (this is the maximum)
- Intensity on the wafer should be as low as possible, a typical magnitude is between 20 and 40.

Remember: The intensity at the cursor position is printed on the lower right border of the window (see *Figure 21*).

*In case the wafer is brighter than the background (this is the common situation for wafers when not using a reflective background):*

- Intensity on the wafer should be on 255
- Intensity on the background should be as low as possible

With improving the intensity contrast, the sensor performance increases. The button "Auto shutter" will give you a first proposal for the shutter speed. The optimal setting in your machine depends on the background light conditions and the job accuracy. A manual fine adjustment brings you to optimal contrast settings with best sensor performance.

To adjust the intensity start with a small *shutter speed* and then bring the bright areas on your image to 255. In the bright areas the intensity should be saturated at 255.

A small value for *shutter speed* will lead you also to small effects on motion blur. Motion blur is a result of the movement of the object during the time needed to capture the image (*shutter speed*). E.g. if the product is moving at 20 m/min and the *shutter speed* is 1.0 ms then the amount of motion blur is 0.333 mm.

#### 4.2.3.2 Contrast

Wafers on poorly reflecting background like metal sheets may reveal a poor contrast since the reflectivity of metal and the wafer may be similar. The edge of the tested wafer may appear less straight than under recommended conditions. To ensure the high quality of analysis nevertheless, the user may consider the following options:

- Change the colour of the illumination to achieve different reflectivity of the materials. SensoPart offers white, red and infrared illumination for cameras and external light sources.
- Adjust *Binarization / threshold factor* in *Expert mode* (*this is found in SensoConfig software on the top menu bar, in View - Expert mode*) for a smoother contour in the green plotted overlay. A *manual* setting of the *wafer brightness threshold* should be limited to lab tests only. For stable mass production always use *Automatic* binarization.
- A smooth contour can be obtained by using *Wafer / Miscellaneous / Contour smoothing* in *Expert mode*. Use *Job / Pre-processing / Dilation* and *Erosion* filters with same areas subsequently.

Some other solutions are described in section "4.2.2 Machine parts in the image". The usage of filters reduces the ability to resolve chips and should be avoided. Further options for unusual conditions for your application can be applied in cooperation with the SensoPart technical support team.

## 5 Software configuration

This section describes how the software tools are used and optimized to meet the requirements of the application. For details on general VISOR® tools see *VISOR® user manual* as well.

To run offline analysis of stored images choose the requested model in the *SensoFind* section *Sensors for simulation mode*.

**The configuration of the VISOR® sensors is performed in the following simple six steps using *SensoConfig*:**

- 1) *Image acquisition parameters with "Job"*
  - This includes the configuration of the Image acquisition parameters illumination, trigger mode and timing
- 2) *Alignment (Advanced version only)*
  - This feature allows to refer all regions of interest (ROI) positions to one fiducial or edge
- 3) *Configuration of the detection characteristics via "Detector"*
  - Tool box for image processing, here are the characteristics of the wafer defined which are tested with the sensor, available tools are listed in *Figure 3*.
- 4) *Adjustment of the needed I/Os via "Output"*
  - Definition of digital I/O and telegram for data transmission
- 5) *Control of the adjustments via "Result"*
  - The results of image processing are displayed on the screen for information and to check the influences of the set parameters.
- 6) *Start sensor*
  - By clicking on this button, the configuration parameters are transferred to the sensor, which then runs autonomously from the configuration PC. Only in this mode the cycle time is displayed on the lower edge of the screen. Please note that outputs will be set or reset according to your parameters. No liability is taken for damage occurring from this action.

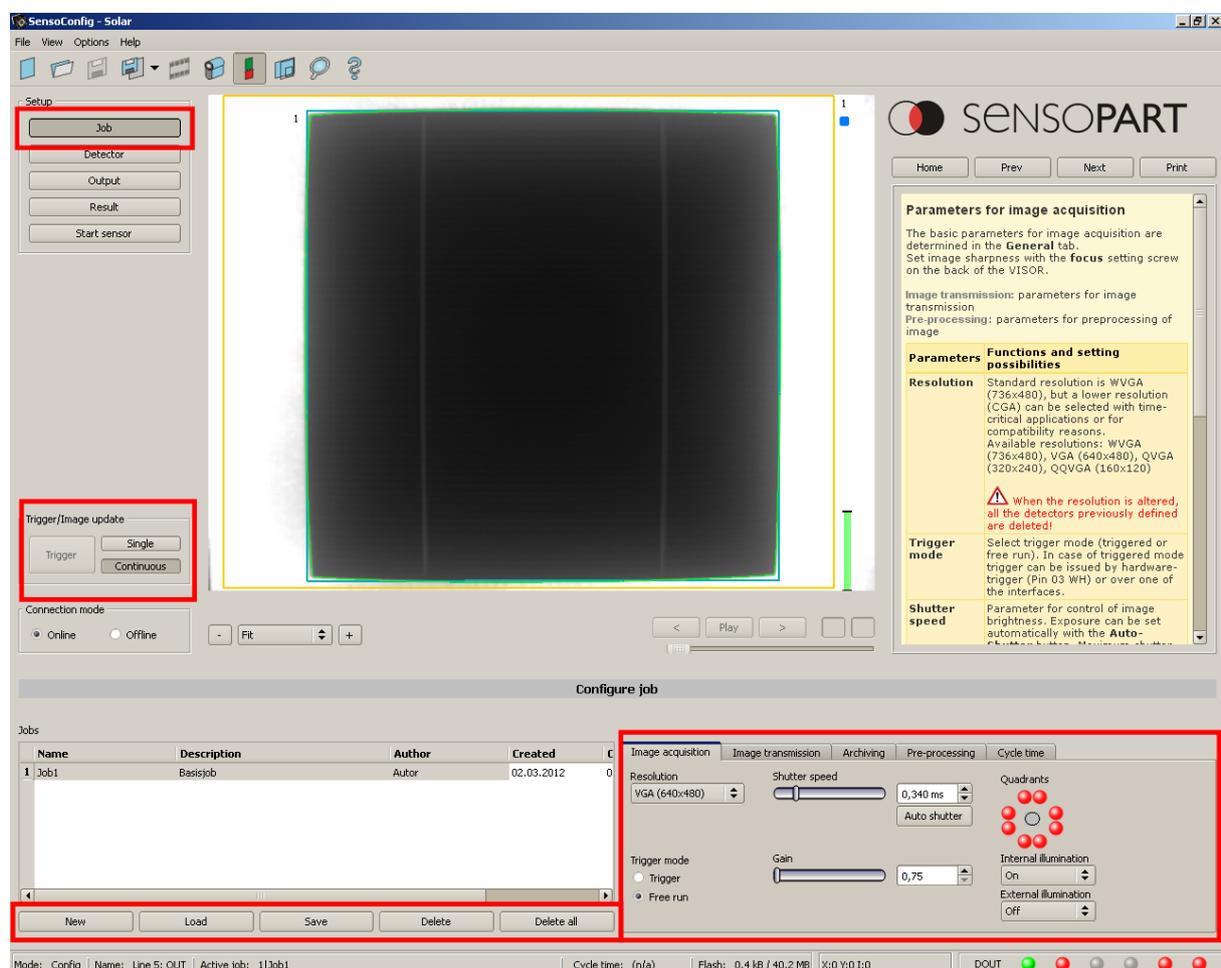
**Unless stated otherwise, all operations are done running *SensoConfig* without activating the *Expert mode*.**

## 5.1 Image acquisition parameters with "Job"

After mechanically mounting and electrically connecting the camera, it will be necessary to set the shutter speed, gain and focus to ensure a sharp, clear, high contrast image. This basis setup provides best performance of the sensor and will lead you to an optimal productivity. The most relevant controls are explained in this section *5.1 Image acquisition parameters with "Job"*, a complete description can be found in the *VISOR® user manual*.

Ensure before starting that your sensor provides a sharp image. The focus is adjusted by the use of the small slotted screw in the rear of the camera (please use the screw driver provided to avoid any damage). See section "4.1.6 Focusing".

To implement these basic settings go to "Job" → Image acquisition as shown in *Figure 29*. All settings are saved in a so-called *Job* file. This job file can be saved with the button "Save", (see *Figure 29*), e.g. to make a backup or to use the settings in a similar machine. To load a job file use the "Load" button. With the "Delete" button single jobs are deleted, with the "Delete all", all jobs can be deleted. With the "New" button, a new *Job* file is created.



**Figure 29: SensoConfig software interface**

Several jobs can be stored on the camera depending on the model (see Figure 3: Product line overview of VISOR® Solar). The jobs can be switched either by Ethernet command, serial or parallel commands or via toggling a digital input.

**Resolution:** Always choose the VGA (640x480) resolution since the wafers and cells have a square shape.

**Trigger mode:** With choosing the trigger mode as “free run” your sensor will continuously take pictures, this mode is preferred when you are setting up the camera. Immediately, you will see the results of your changes. It is also possible to run the sensor in free run mode in the production setting, with the result of a asynchronous data acquisition. The better setting in your production will be the trigger mode, then the sensor takes pictures when they are needed from your machine.

The setting of the trigger characteristics (e.g. a time delay) will be described later in section “

#### 5.4.4. Timing

The trigger from the machine can be simulated by the trigger button on the left of your screen.

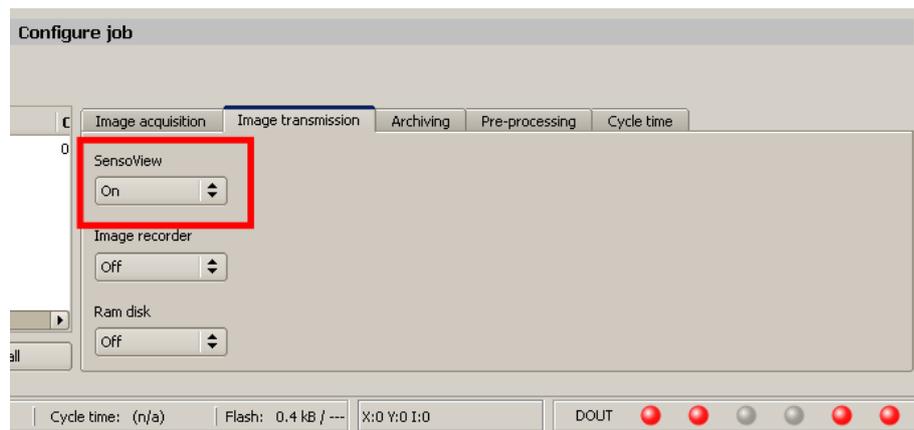
**Shutter Speed:** Use the scroll bar to adjust the right shutter speed as described in section “4.2.3.1 Shutter speed”. While using the reflective foil the shutter speed as a guide will be in the order of 0.2ms to give high contrast between the dark solar cell and the bright reflector (see fig. 4). The shutter speed can be decreased with using the *Gain*, as described in the next break.

**Gain:** Typically, the default setting of 1 is sufficient when dealing with a reflective foil. However, if the image contrast is not high enough, increasing the gain will increase the brightness of the overall image. By increasing the gain, a shorter shutter speed can be achieved. This also lead to smaller effects of a moving wafer or machine vibration to the image quality.

**Quadrants:** With this items you can choose the LEDs which are illuminated just by clicking on them. This feature of the sensor allows you to avoid bad reflections from machine parts or from the wafer which can cause bad image conditions. Usually, all LED are illuminated to ensure a high shutter speed.

**Illumination:** With the menu internal and external illumination you can choose the used illumination condition, per default the internal illumination is on and the external are off. The external illumination can also operate in permanent mode, this is preferred when you will avoid the flash from the illumination, but can shorten the lifetime of your external illumination.

Once the basic settings are done, then we can move on to the calibration and image distortion settings. Usually no configurations in the tab “*Image transmission*” have to be done, since the transmission to *SensoView* per default is *On* (see *Figure 30*). This setting is used to transfer your sensor images to the program *SensoView*.



**Figure 30: Image transmission**

The tabs “*Archiving*”, “*Pre-processing*” and “*Cycle time*” are only needed in special applications, see the *VISOR® user manual* for further information.

After the illumination settings are done and a sharp image is available you are now able to teach the sensor in how to analyse the images (e.g. which characteristics have to be checked or which measurements have to be done).

## 5.2 “Alignment” (Advanced version only)

This feature is available in the *Advanced* version only. If you are using the *Standard* version, you can skip this section.

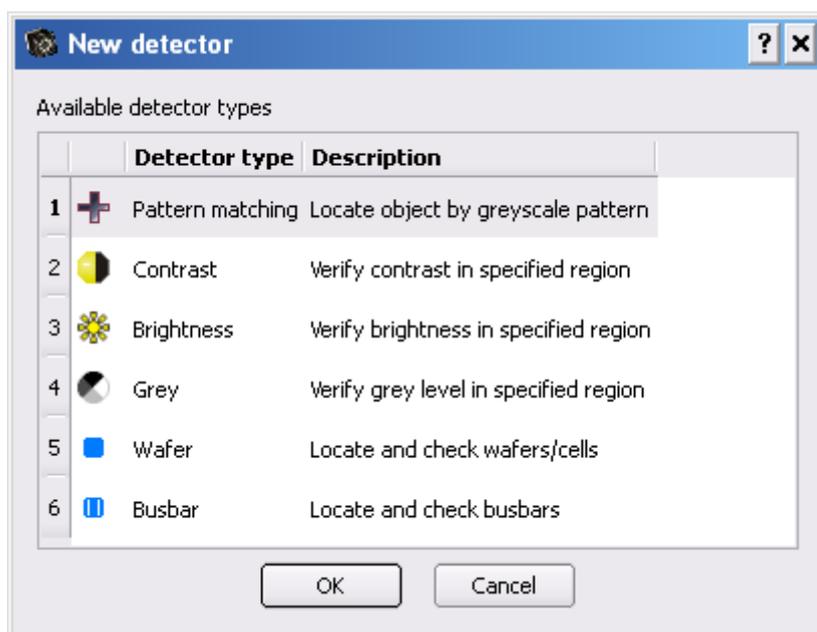
The *Alignment* option is used when a large field of view is used and a fast preliminary position is helpful. This position can be used to determine the position of a smaller region of interest (ROI) which causes a faster processing of all measurements and a higher throughput of the VISOR® sensors.

## 5.3 Configuration of the “Detector” characteristics

The detector sub menu is designed to choose the method of image processing: Which measurements are done and which characteristics are tested. One image can be processed with one or several detectors. To analyse cells, typically a *wafer* and a *busbar* detector have to be implemented. In case fiducials are to be considered a *pattern matching* detector is used for each of them.

The settings needed in every application of the sensor are described in the following sections until “5.3.4 Checking the thresholds with Result”

To implement a new measurement to be performed from the sensor, a new *detector* has to be applied. By clicking on the “New” button (see *Figure 29*, when using a sensor with factory settings, a new *detector* will be created automatically). A window like this will be shown:



**Figure 31:** Detectors available in the VISOR® Solar Advanced product line.

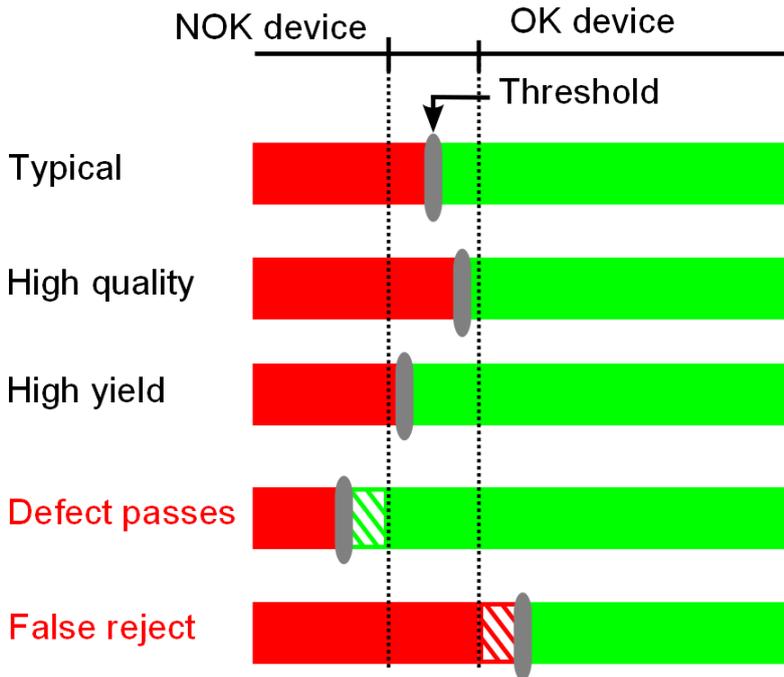
The VISOR® sensors are able to run several tests or measurements on your wafer. All the tests results are provided in the section *Result*. Typically the results are compared to user defined limits and ranges defining the PASS / FAIL criterions. To generate a PASS a wafer has to PASS ALL criteria activated by the user (criterion1 AND criterion2 etc.).

The following paragraph provides a basic guideline how to define limits and ranges.

A typical set-up of the sensor criteria provides the following results: All good sample devices PASSES the tests and all defect parts FAIL (see *Figure 32*). To reach this aim, some devices (OK and Not-OK ones) should be tested under several operating modes with some start criteria, and then the criteria should be re-adjusted until they provide your production needs.

To provide a high reliability of your tests you may tighten the criteria, this means the number of wafer damages identified by the sensor increases and you lower the risk of production downtime caused by broken wafers. If the quality criteria are too tough, you get a possibility of false rejected wafers.

To provide a high yield you may lower your criteria. This implies the possibility of getting a PASS result of a bad device with all the bad impacts on your production.



**Figure 32: Setting of the threshold parameters**

For typical applications in the solar industry choose a "Wafer" detector (number 5 in *Figure 31*). The other kinds of detectors can be used for special tasks and will be described later or in the *VISOR® user manual*. The following description is written for the *Wafer detector*, unless its state otherwise.

Before adjusting settings ensure that your wafer is complete inside of the yellow search region of interest (*ROI*) of your detector image. You can resize the *ROI*, with drag and drop the black dots on the edges of the *ROI* to the needed position. The change of the position of the *ROI* is also done with drag and drop to the needed position. To rotate the *ROI* click on the arrowhead of the arrow on the right side and rotate the *ROI* around the centre of the rectangle.

### 5.3.1 Calibration

For typical applications in the solar industry choose at least a "Wafer" detector (5<sup>th</sup> item in *Figure 31*). The other detectors can be used for special tasks and will be described later or in the *VISOR® User Manual*. The following description is written for the *Wafer detector*, unless it is stated otherwise.

Before adjusting settings ensure that your wafer is complete inside of the yellow search region of interest (*ROI*) of the detector. The *ROI* can be resized with drag and drop by shifting the black dots at the edges and corners of the *ROI* to the needed position. The change of the position of the *ROI* is also done with drag and drop to the needed position. To rotate the *ROI* click on the arrowhead of the arrow on the right side and rotate the *ROI* around its centre.

When starting to use a wafer detector an initial calibration is recommended, which is done by just three clicks, see *Figure 32*:

- 1.) Go to *Detector* and choose the tab *Calibration*
- 2.) For a 6 inch cell or wafer just activate the *mm units*
- 3.) Finally press "*Calibrate to wafer*"

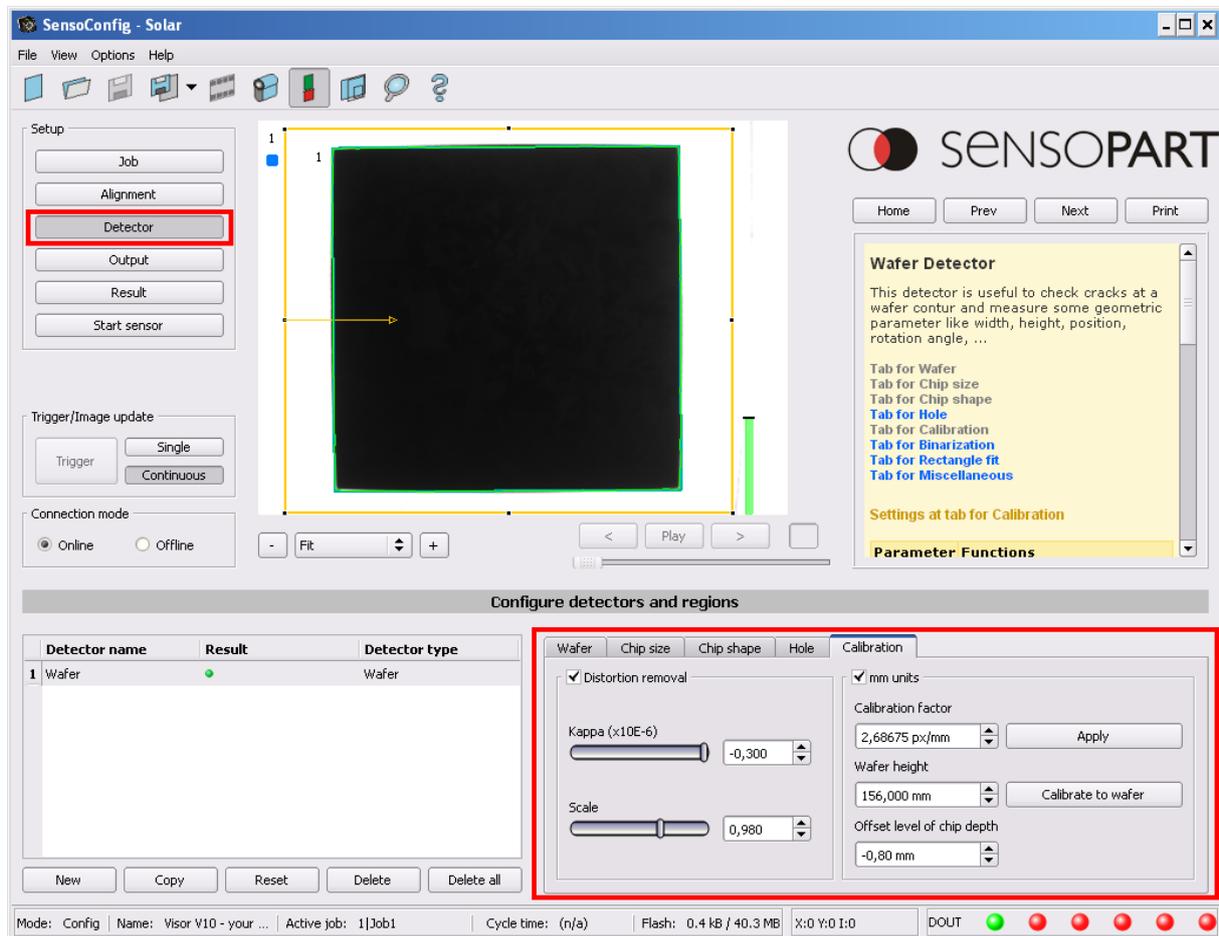


Figure 33: Using *Wafer Detector / Calibration* the camera is calibrated within three clicks.

The meaning of the controls on the calibration tab is as follows:

- **Distortion removal:** The usage of cameras with internal 6 mm lenses allows small working distances. However, a slight optical distortion of the square object is observed in the image. For best results with the V10 6 mm cameras ALWAYS activate the distortion removal this can be found under *Detector / Calibration tab / distortion removal* without changing the default values. Since other camera models do not cause any significant optical distortion, do not activate *distortion removal* with these models.  
Default values are  $Kappa (x10e-6) = -0.300$  and  $Scale = 0.980$   
Please note that just the algorithms and the overlay of their results consider a distortion removal. For reasons of speed, the images shown on the screen are not compensated. This may yield to apparent discrepancies during the configuration, but has no effect on the quality of the performance.  
Activating "Calibration / Distortion removal" results in 18 ms processing time.
- **mm units:** All cameras operate on the basis of pixels. To switch to more user-friendly metric dimensions, the user should activate *mm units* (also under *Detector / Calibration tab*).
- **Calibration:** The calibration factor for the translation of pixels to mm units can be derived most easily from a wafer being exposed to the camera. By default its *wafer height* is assumed to be 156.0 mm. For 5 inch wafers it should be changed to 125 mm. Clicking on *Calibrate to wafer* the *calibration factor* is computed and displayed. Alternatively, the calibration factor can be set manually. In *Appendix A: Test sample* a wafer with a size of 156 mm and some chips is attached, which can also be used to calibrate the sensor.  
To reproduce the calibration factor it is recommended to use the same wafer or a longer-lasting metal sheet during all calibrations. Whenever the mechanical setup or the focus is adjusted, the last calibration step should be repeated.
- **Offset level of chip depth:** The internal lenses yield to a small blurring of the image, which influences the detection of chips. To compensate this effect a default offset of -0.4 mm is provided, which compensates this effect. This setting should not be changed for the internal 6 mm and 12 mm lenses of the V10 models.

### 5.3.2 Teaching the sensor your machine configuration

Since the sensor is made to work in a lot of different environmental conditions, a few settings depending on the individual machine configuration are needed. This includes the contrast setting between the wafer and background, the shape and size of the wafer and machine parts in the image (e.g. from conveyor belt) which have to be blanked.

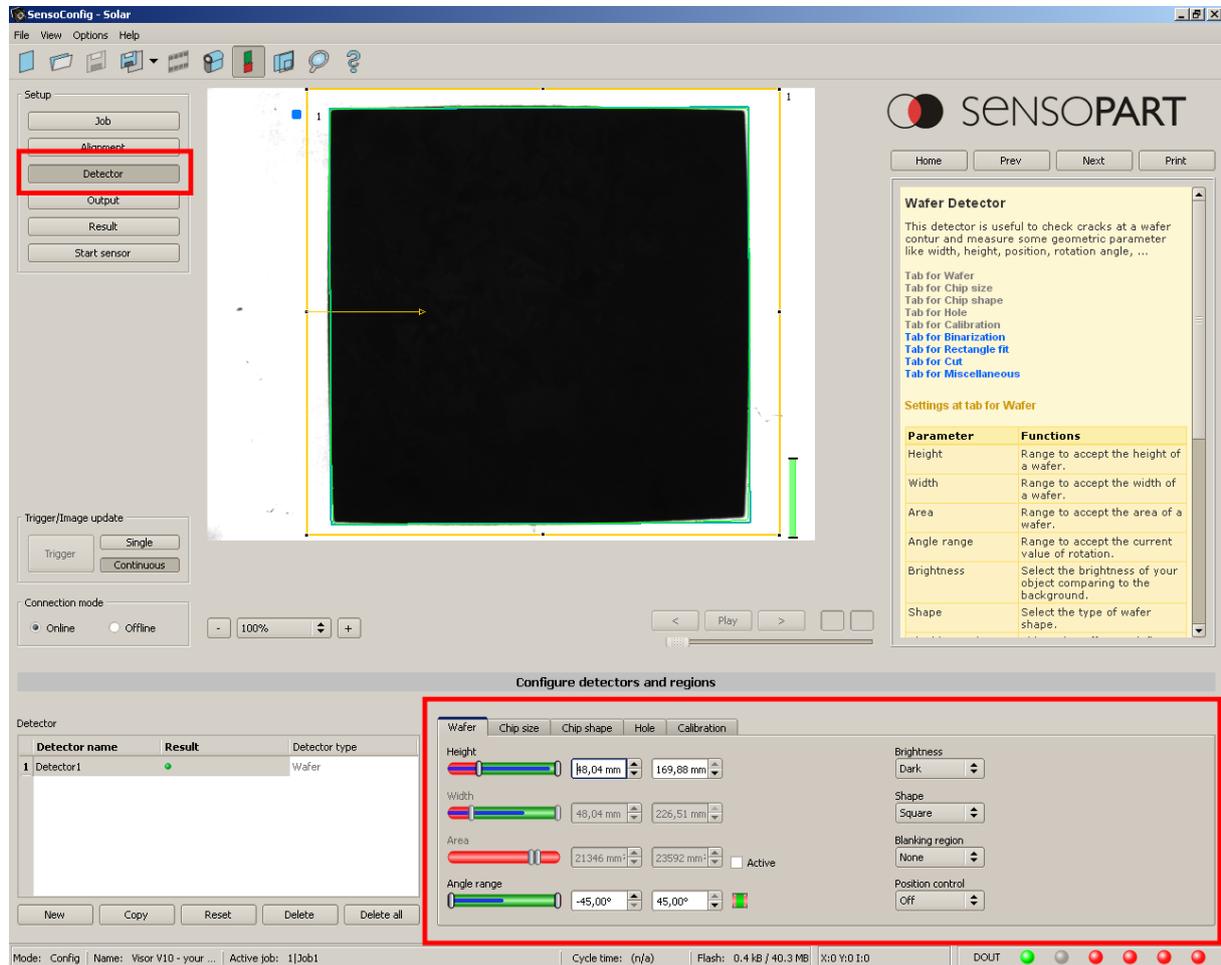


Figure 34: Applying the *wafer* detector for position detection and size verification

First, choose the contrast setting between wafer and background with the "*Brightness*" menu on the left. If your wafer appears brighter than the background choose "*Bright*". If it appears darker than the background choose "*Dark*". The default setting is "*Dark*".

With the "*Blanking region*" menu you can choose the number of *Blanking regions* inside the image to avoid effects on the wafer analysis from machine parts in the image. In the image shown they appear as violet rectangles like in *Figure 27* at section "*4.2.2 Machine parts in the image*". The position of the *Blanking region* can be changed by drag and drop. Their size is changed by drag and drop of their edges to the right position. By drag and drop of the arrowhead in the rectangle you can rotate each *Blanking region* similar to that of the *ROI*.

Please note, that the blanking regions must not split the wafer completely into separate parts (so called "*blobs*"). All pixels of a wafer must remain connected without considering blanking regions.

### 5.3.3 Setting of the dimension measurement

As a standard the *wafer height* and *width* is determined without extra time. The result is compared to the acceptance ranges set by the user. Since *height* and *width* are determined independently, these values may differ a bit, even when a quadratic wafer is tested. A absolute accuracy better than 50 µm and a overall repeatability of a few microns can be obtained in determining the wafer dimensions.

Now you have to choose, if you want to compare the *width* and the *height* to two independent thresholds or to one. Usually, both dimensions are compared to one value by choosing the "*Shape*" as *Square*, which is also the default. Both measured wafer dimensions are then compared to the ranges set with "*Height*". The ranges can be set using the number edit or the slider. In the slider you see the excluded range as a red region, the accepted range as a green region and the actual measured value as a blue line.

In case different tolerances shall be applied to the *width* and the *height* the parameter *Shape* has to be set to *Rectangular*. Then, the wafer dimensions are compared independent to the ranges set by *Height* and *Width*.

This dimension feature allows the user to

- Distinguish between 5 and 6 inch wafers.
- Run a quality control of the wafer dimension as shown in *Figure 34* with just 1 mm tolerance
- Sort out double wafers: In case two adjacent wafers picked from one box could not be separated properly and are placed together on a conveyor typically the size of the two wafers is larger than the size of a single wafer and can therefore be taken as a criterion for double wafers.

Notice should be spent on the following aspects to achieve highest accuracy:

- Necessary
  - Stable mechanical setup – no vibrations of the wafer or camera
  - Camera's direction of view is perpendicular to the wafer
  - Clear edges of the wafer in the image
  - *Wafer / brightness* and *wafer / shape* is set correctly.
  - Under all conditions the wafer must be entirely in the yellow 'search' region of interest (*ROI*)
  - Visible parts of the machine close to the wafer are masked using *blanking regions*
  - Low value of *shutter speed*, lower than 2 ms
- Recommended
  - Low value of *shutter speed*, preferably lower than 1 ms
  - For position detection the wafer should not move during image acquisition, see below.
- Optimized
  - The center of the image is adjusted to the average wafer position
  - The camera has been powered on >1 hour before the calibration
  - In case of shutter speed >0.5 ms: Constant or no ambient light
  - Optionally, fixed reference positions are recorded in parallel, see section "*5.3.6 Fiducials*"

*Width* and *height* are defined as the maximum extension of the wafer and are insensitive against chips. To determine the area of the wafer without considering potentially missing parts of chips, set the control *wafer / area* to *active*. The additional cycle time to perform *area* checks is typ. 16 ms with V10 in VGA resolution. To determine the area activate the "*Area*" option. This feature allows you to distinguish between a monocrystalline and a polycrystalline wafer in an simple way if they have different areas. Most monocrystalline wafers have a chamfer, the polycrystalline don't. If the *Area* criteria is activated and causes a FAIL the sensor will stop the analysis and therefore no further parameters will be checked.

With the "*Position control*" menu you can choose if the sensor is checking the position of the wafer or not. The default of this function is "Off". There are two possible shapes of the tested regions: a rectangular or an elliptical region. The position and size of the position region (which appears as a blue rectangle/ellipse in the camera image) can be changed in the same way like the blanking region which is described above. The sensor tests, whether the centre of the wafer (appears as a light blue cross) is inside of the tested region.

With a controlled setup as indicated previously an absolute accuracy better than 50 µm and an overall repeatability of a few microns can be obtained for the position of the wafer. The objective of this section is to guide users in obtaining the best performance in their application.

Moving objects may be observed by the camera as well. The systematic error on the position detection can be calculated by the inbuilt trigger delay time (1 ms) + half the shutter speed (e.g. 0.2 ms / 2) with both values being multiplied by the transport speed (e.g. 0.05 m/s). Thus, in this example the output value is shifted systematically by 0.055 mm in the transport direction. With the knowledge of the transport speed the PLC may compensate this effect.

The angle observed is compared to the "*Angle range*". The range of the accepted angle can be chosen using the slider and the number edit as before at the adjustment of the "*Height*" of the wafer.

Stable imaging conditions lead to a constant green overlay of the wafer edge and to almost constant values of the wafer position shown in *Results / Wafer / Center X, Center Y* and *Angle*. With optimized setups shown in *Figure 1* subsequently recorded positions do not vary by more than the displayed resolution: 1 µm.

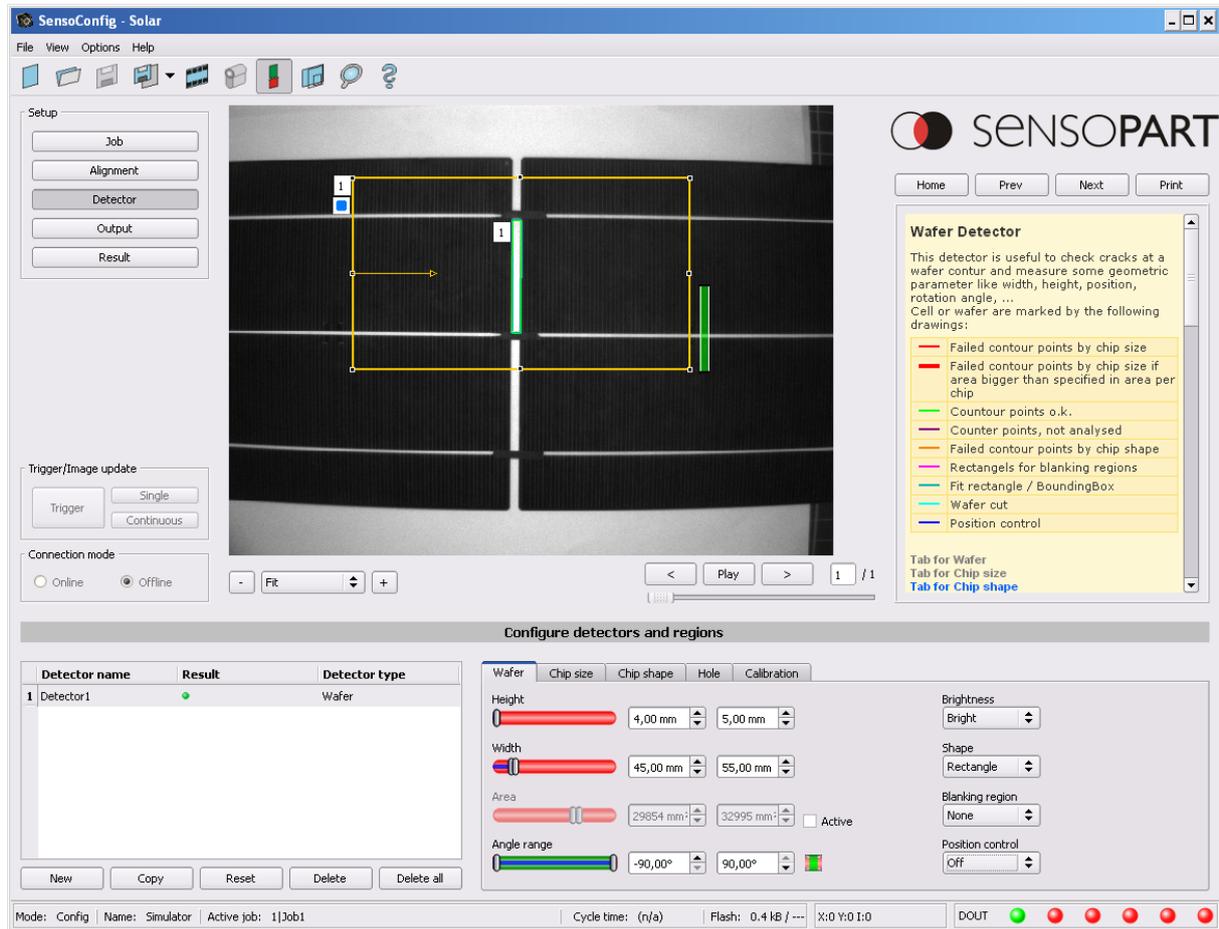
The resulting position can be transmitted via Ethernet or serial bus to a PLC or robot controlling unit. Alternatively, the sensor may compare these values against user settings to perform a PASS / FAIL decision and to control one of digital outputs for this purpose.

Using a V10 model in VGA resolution the standard deviation of the repeatability is typ. 0.5 µm. respectively 0.001° in a setup like described in *Figure 1*. This outstanding repeatability underlines the high precision and reliability of the algorithm employed in this product line. The average cycle time to perform this operation is just 43 ms without *distortion removal*.

### 5.3.3.1 Measurement of wafer and cell distances

With the *Wafer Detector* it is also possible to measure the distance between two wafers. To do this, create a new *Wafer Detector*, choose the *Brightness* as *Bright*, *Shape* as *Rectangle* and define the ROI in a proper way.

An example for a string inspection is shown in *Figure 35*. The distance is given as *Height*, since it's the shorter side of the ROI.



**Figure 35: Typical setup of a distance measurement**

This easy setup provides further very valuable information: The width is a quality measure for the presence of the two ribbons within the ROI. If one of them is missing, the *width* will increase significantly. Adding a second wafer detector the presence of the lower ribbon can be performed as well.

### 5.3.4 Checking the thresholds with Result

After setting the initial thresholds of dimensions and position, it is useful to check the result of further tests. These results of the sensor are shown in *Result*. With the knowledge of the results of your measurement your thresholds can be re-adjusted (as described before).

By clicking on the *Result* button you get an image like *Figure 36*. On the right, the *Statistics* are shown of all images taken by the sensor since starting it, or since resetting the *Statistics*.

On the left are the results of the actual image taken by the sensor, in respect to the actual *Detector* used. The following description is unless stated otherwise in respect to the *Wafer Detector*. The name of the actual *Detector* is grey marked in the small window *Detectors* on the left.

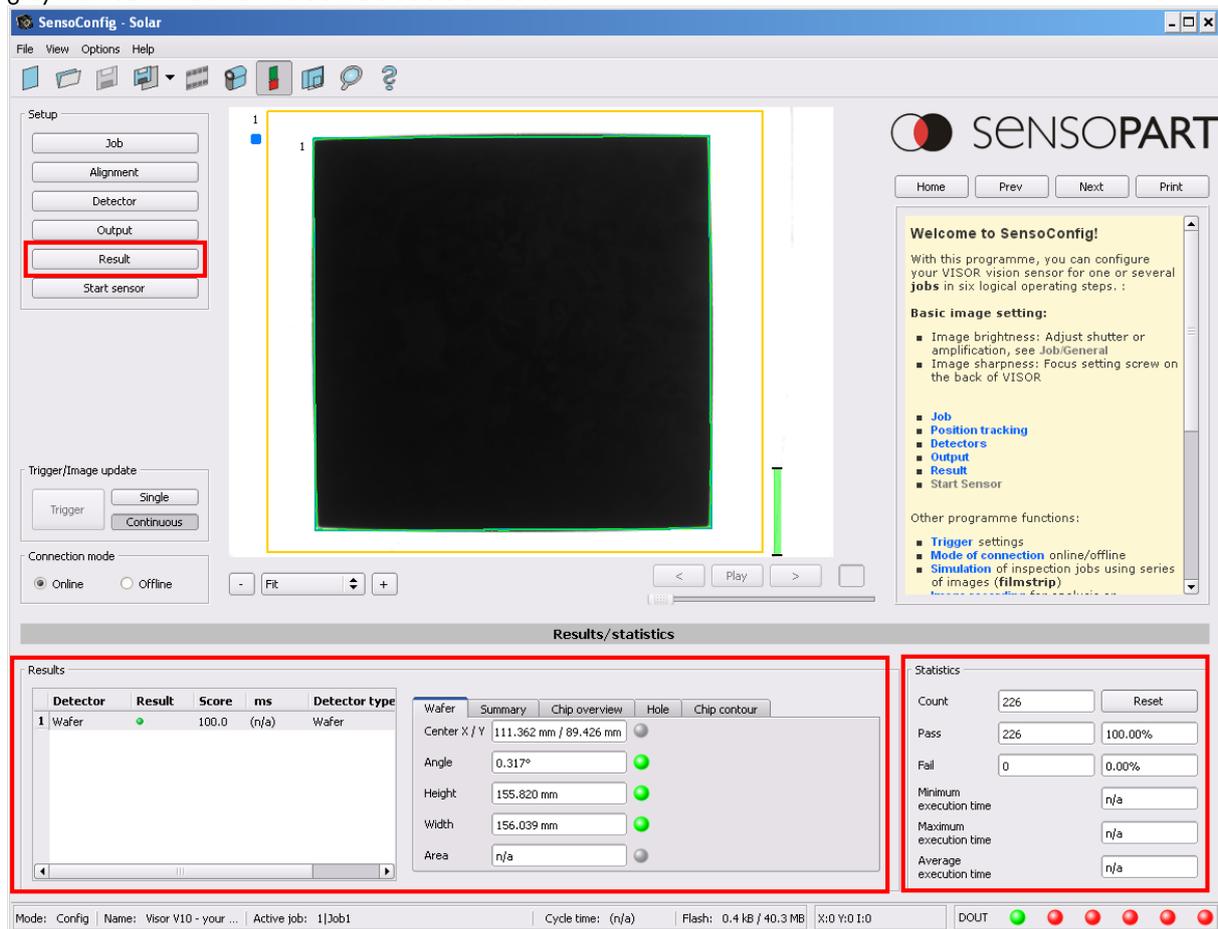


Figure 36: Screenshot of the first tab of *Result*

In the *Wafer* tab the main measurements of the actual image are summarized: The *Center* position, the *Angle*, the *Height*, *Width* and the *Area*. These values are compared from the sensor to the threshold and therefore the wafer gets a PASS or a FAIL result. The green or grey dot gives you the information which test is activated or not.

It is useful to check if the values shown from the sensor are reasonable or if some misinterpretations are done e.g. from a wrong or old calibration.

### 5.3.5 Configuration of chip detection: "Chips"

As a result of sawing or handling of wafers chips may break out of them during any step of the processing. In the following the chips may propagate and cause a complete breakage of the wafer and a contamination of the production lines. Sharp defects like triangular ones will likely propagate. Due to their shape they are called 'shark teeth'. More flat defects are called 'mouse bites' or 'blunts' and propagate less likely. A typical requirement in production is to detect chips which exceed 1 mm.

The VISOR® Solar sensors offer two different tools for such detections: *Chip Size* and *Chip Shape*.

- The *Chip size* tool detects the deviation of the observed wafer edge from the fit of an ideal geometry. The tool is easy to set up, fast in operation and largely independent of the shape of the defect. The tool may be used to detect the area of the chip.
- The *Chip shape* tool detects sharp edges of the contour. It provides the highest sensitivity and can detect chips down to 0.5 mm. However, it requires more processing time and is insensitive to very soft blunts.

The performance of the two alternative tools is described *Figure 7*. Both algorithms are able to distinguish chamfers from chips.

If the chip detection is operating, it is useful to check the dimensions of the wafer to sort out wafers which are broken in an ideal rectangle.

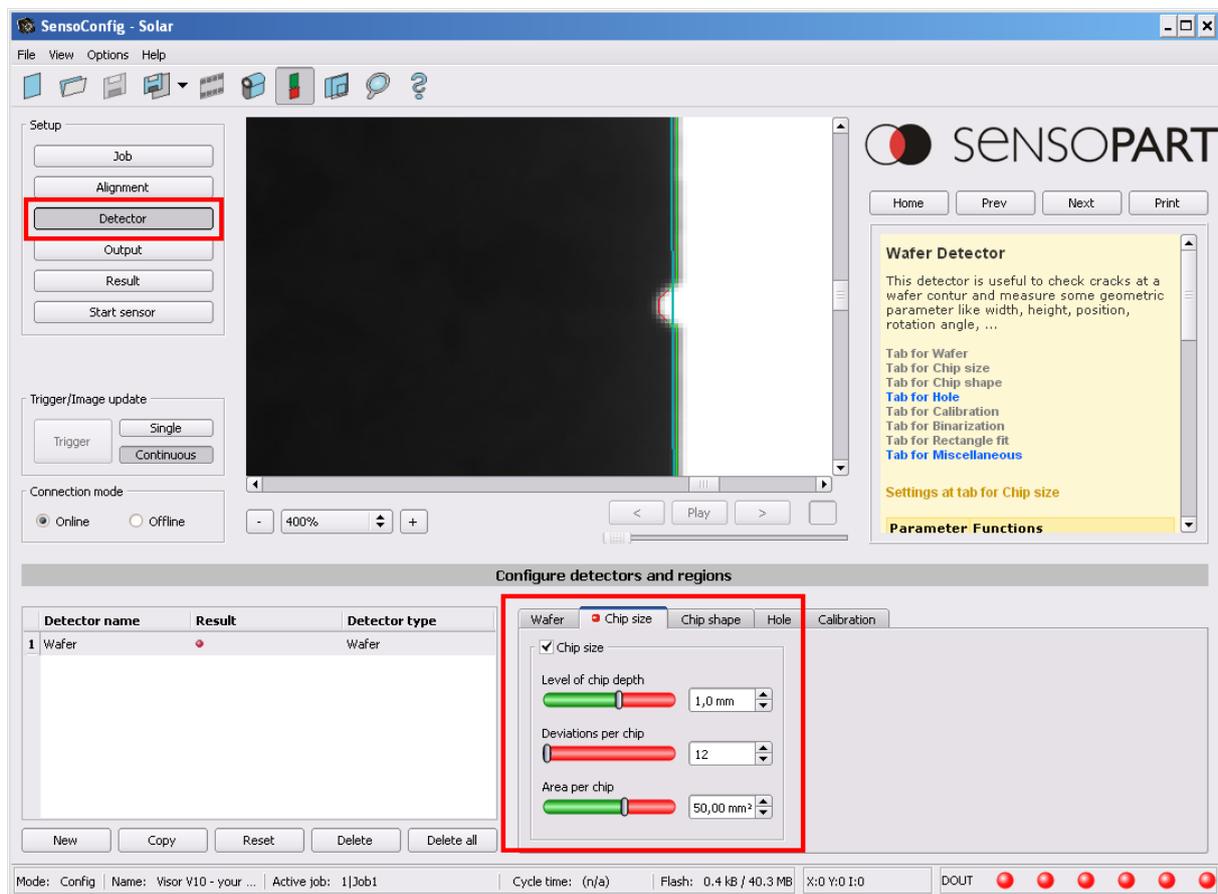
As stated before in section "*5.3.3 Setting of the dimension measurement*", the thresholds of the chip detecting tools should be set up carefully, with the implications of *Figure 32* in mind. Also check the results after setting new thresholds.

### 5.3.5.1 Chip Size tool

Using the *Chip Size* tool the analysis of chip is performed in two subsequent steps. It detects potential chips due to deviations in the geometry fit. The found potential chips may be filtered with regard of their extent to provide stable analysis results.

1. The observed depth of a potential chip exceeds the threshold defined as *Level of chip depth*. Remark for specialists: The depth of a chip is determined by the size of deviation of the observed wafer edge from the turquoise marked fit of an ideal square. This provided the name *Chip Size* tool.
2. To cause a FAIL the chip additionally either violates 1. AND (2a. OR 2b.)
  - a. above rule of chip depth for at least the number of pixels defined in *Deviations per chip*
  - OR
  - b. the limit defined in *Area per chip*

In the example below, a chip is detected and shown in eightfold magnification. The red line indicates locations violating above distance check of the fit - condition 1 FAILED. These deviations are observed for 15 times - condition 2a causes a FAIL. Concluding, the chip size tool rejects the wafer. Since the two previous conditions FAILED the comparison to *Area per chip* becomes irrelevant in this case.



**Figure 37: Applying the *Chip Size* tool:**

Locations exceeding the *Level of chip depth* are shown in red. If additionally, the *Area per chip* is exceeded the line will be **broad red**.

Please note that the *Level of chip depth* is not identical to the physical dimension. Due to the finite camera resolution and effects of the optics there is an offset between the two, which is compensated by a *calibration* parameter, see section "5.3.1 Calibration". *Figure 7* reveals the detection limits with the *Level of chip depth* used in above example.

The average cycle time to perform this operation on a good wafer is 13 ms. Typical chips increase the cycle time by a few ms. However, analysing several massive defects in one wafer, this tool may take 24 ms or more.

### 5.3.5.2 Chip Shape tool

The *Chip Shape* tool scans for sudden angle deviations along the edge of a wafer. To generate a fail signal, the chip violates

1. The set *Level of chip depth*
- AND
2. The set *Angle deviation*, which defines the sensitivity of the algorithm

The locations representing a chip according to this scanning method are shown in orange. To illustrate the performance of this tool, it has been applied to the same chip like used in the previous section keeping the default parameters.

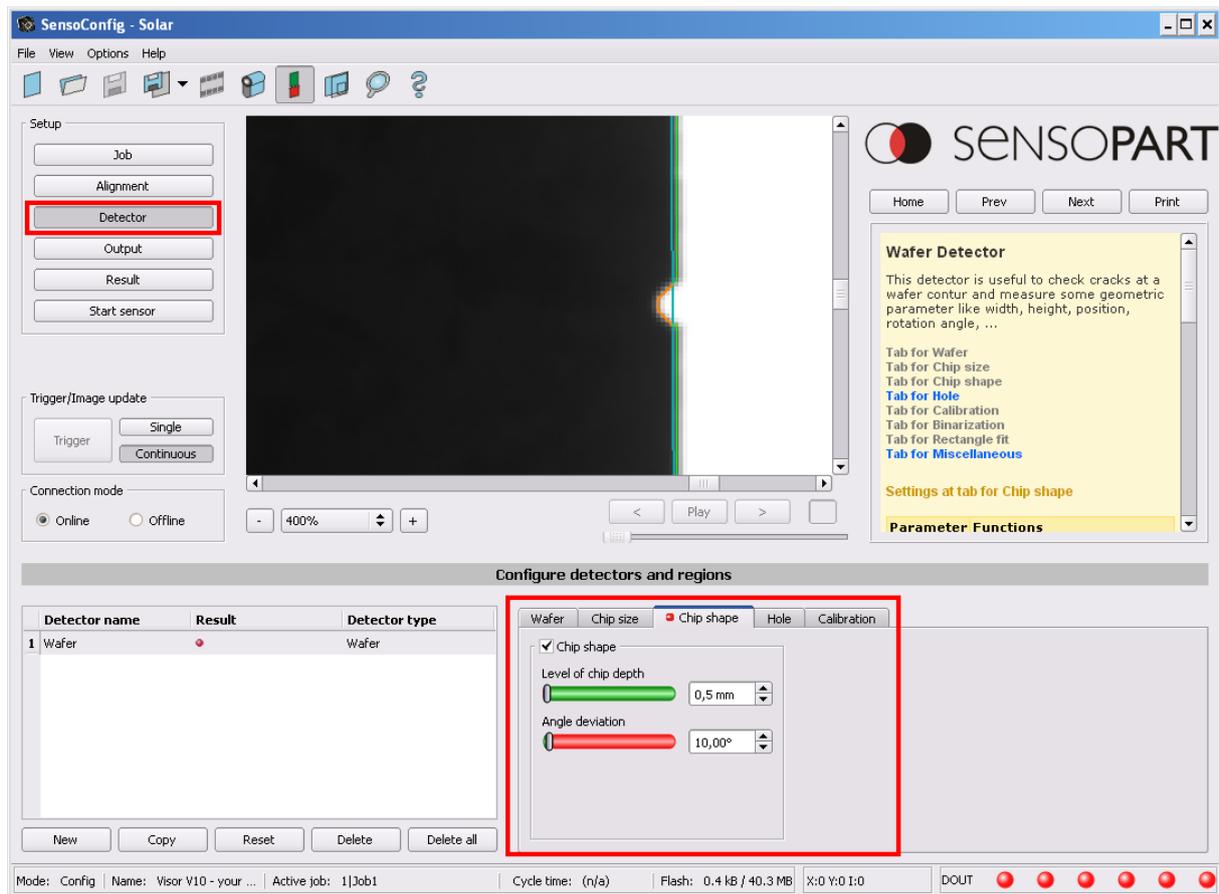


Figure 38: Applying the *Chip Shape* tool to the same chip shown in Figure 37

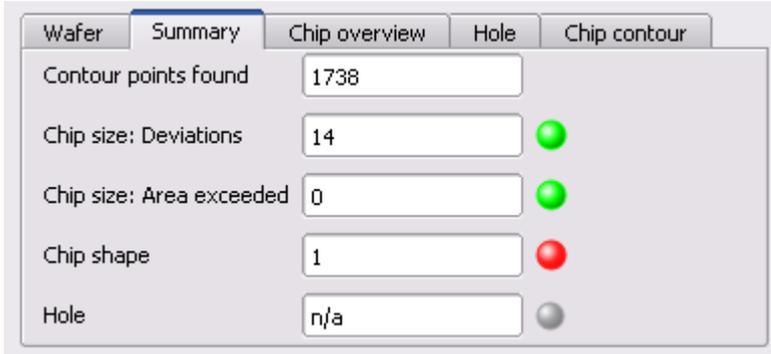
Detected chips are shown in orange.

Above chip could be detected reliably with *angle deviation* set between 10° and 140°. Since just the peak of the chip is observed, this tool cannot differentiate between large and small chips of the same shape.

The average cycle time to perform this operation on a good wafer is 32 ms. Typical chips increase the cycle time by a few ms. However, analysing several massive defects in one wafer, this tool may take 48 ms or more.

### 5.3.5.3 Checking the results of the Chip tools

To check the results of the Chip tools, press the button *Result* (a window like in *Figure 39* will be shown). In the tab *Summary* the results of the Chip tools are shown:



Label	Value	Status
Contour points found	1738	
Chip size: Deviations	14	Green
Chip size: Area exceeded	0	Green
Chip shape	1	Red
Hole	n/a	Grey

Figure 39: Tab *Summary* of the *Result* sub menu

- **Contour points found** gives you the number of contour points used to define the contour line of the actual wafer. The dot on the right is green if this option is active or grey if its not.
- **Chip size: Deviation** gives the number of contour points which have a deviation from the calculated “ideal” contour of the wafer. These points are listed with their exact positions in the *Chip contour* tab.
- **Chip size: Area exceeded** provides the number of chips found on the wafer with violate both the criteria of the *Chip size* tool: *Level of chip depth* and *Area*, see section “5.3.5.1 Chip Size tool”
- **Chip shape** gives the number for the *Chip shape tool* (section “5.3.5.2 Chip Shape tool”).
- **Hole** represents the number for found holes (section “5.3.7.1 Holes, Cracks and Stains”). At max. 10 holes will be detected.

All found chips are listed in the *Chip overview* tab. If the *mm units* option (under *Detector / Calibration*) is activated all the given positions and results are in mm, to find a chip on the screen it may be useful to deactivate this option.

To check the adjusting of your threshold it may be useful to check if all found chips are needed to identify as chips. It is also possible, that different settings are more useful to your production needs as discussed in section “5.3 Configuration of the “Detector” characteristics”.

### 5.3.6 Fiducials – Pattern Matching Detector

Fiducials are used to trace changes of the coordinate system and to compensate for them. To ensure a long-term stability and reliability for accurate position detection it is strongly recommended to implement two fiducials in the machine and to detect their position.

Moreover, is beneficial in machine configurations with two cameras, one fixed and the other mobile on a robot. To do this, two fiducials like screws have to be placed at fixed locations fixed close to the object. By detecting them with the sensor, a coordinate system in a plane is fixed and all positions and measurements can be referred to that coordinate system. When the fiducials are detected by two sensors, their coordinate systems are synchronized dynamically. A possible configuration to this purpose is shown in *Figure 40*.

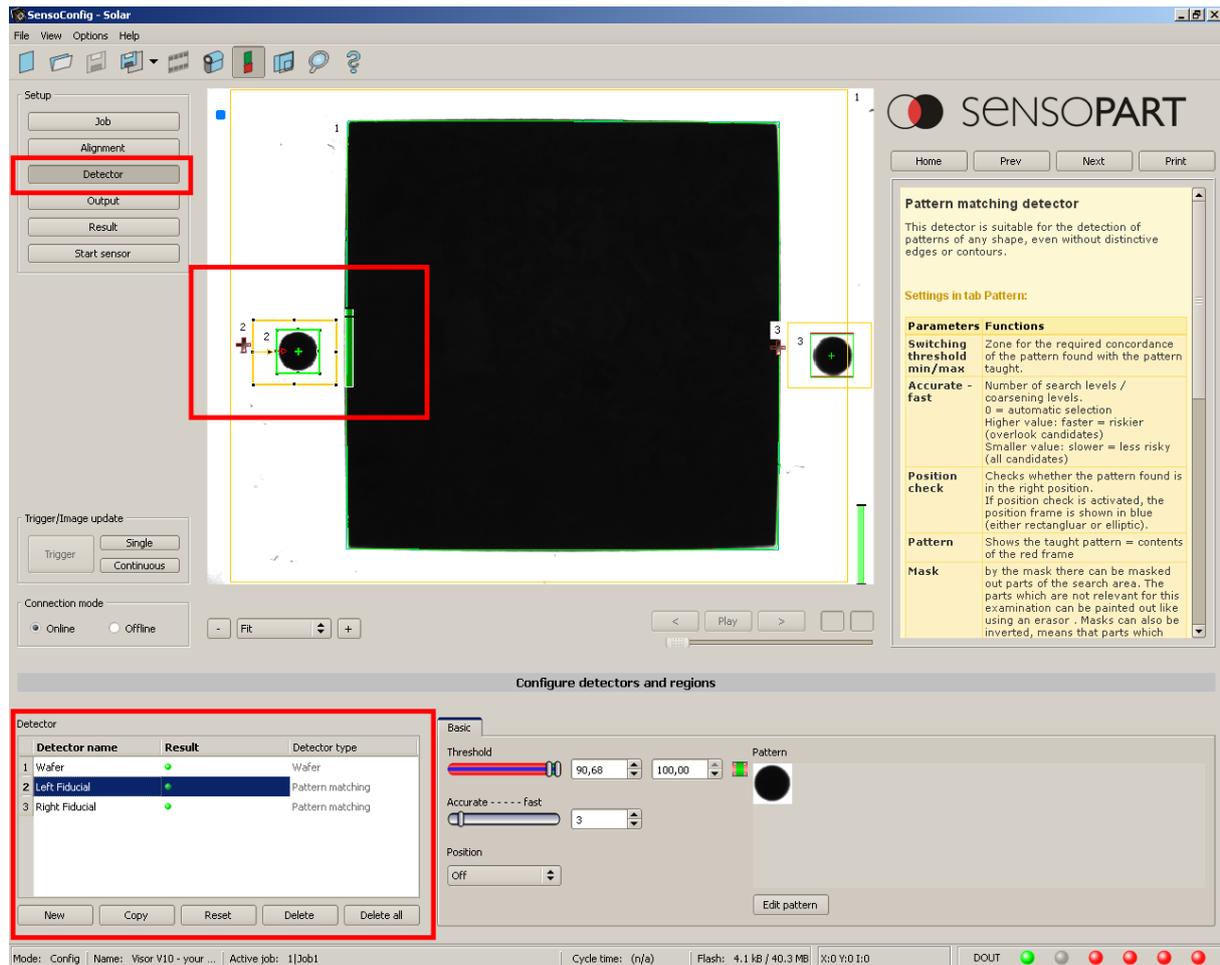


Figure 40: One possible configuration to use the fiducial option.

The fiducials should be fixed on the reference frame with this following characteristics: Their position should be at two sides of the wafer, on a line through the centre of the. The fiducials are detected with two *Pattern matching Detectors* by the sensor. These *Detectors* are added with the *New* button described in section "5.3 Configuration of the "Detector" characteristics" - 1<sup>st</sup> item in *Figure 31*.

To configure the *Pattern matching* detector, the steps are similar to the steps of configuration of the *Wafer* detector. First, the yellow region of interest (*ROI*) has to be defined, the size and position of the *ROI* depends on the size of your fiducials. Only patterns inside of the *ROI* are registered and compared to the saved pattern. To teach a pattern, the red rectangle has to be positioned as close as possible to the actual positions of the fiducials (it is very useful to make use of the possibility to zoom into the actual image). The actual detected pattern is marked with a green rectangle, this is usually at a likewise position as your red rectangle so you will see one red/green rectangle instead of two rectangles.

Please note, that the *Pattern matching Detector* will only provide the center of the fiducial as position once the center of the green box has been initially moved to the center of the fiducial.

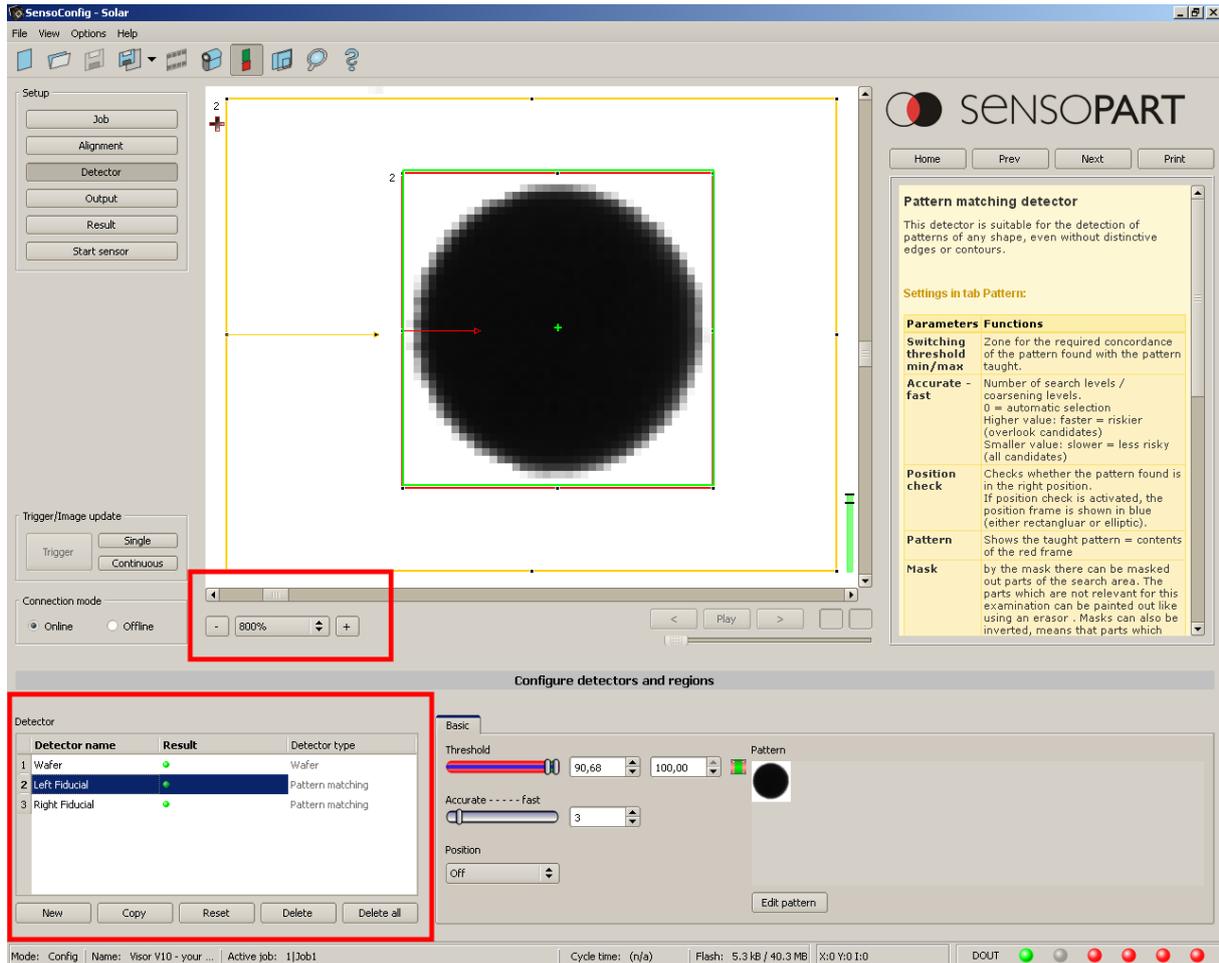


Figure 41: Configuring the *Pattern matching detector* for a round fiducial.

While using similar fiducials you can easily transfer your saved pattern from one *Pattern matching Detector* to the other with the *Copy* button. Further information on the *Pattern matching Detector* can be found in the *VISOR® User Manual*.

The centres of the fiducials detected by the sensor are used to define the coordinate system, the coordinates of the fiducials are given out via the data interfaces of the sensors. Under the *Result* sub menu the actual positions are listed.

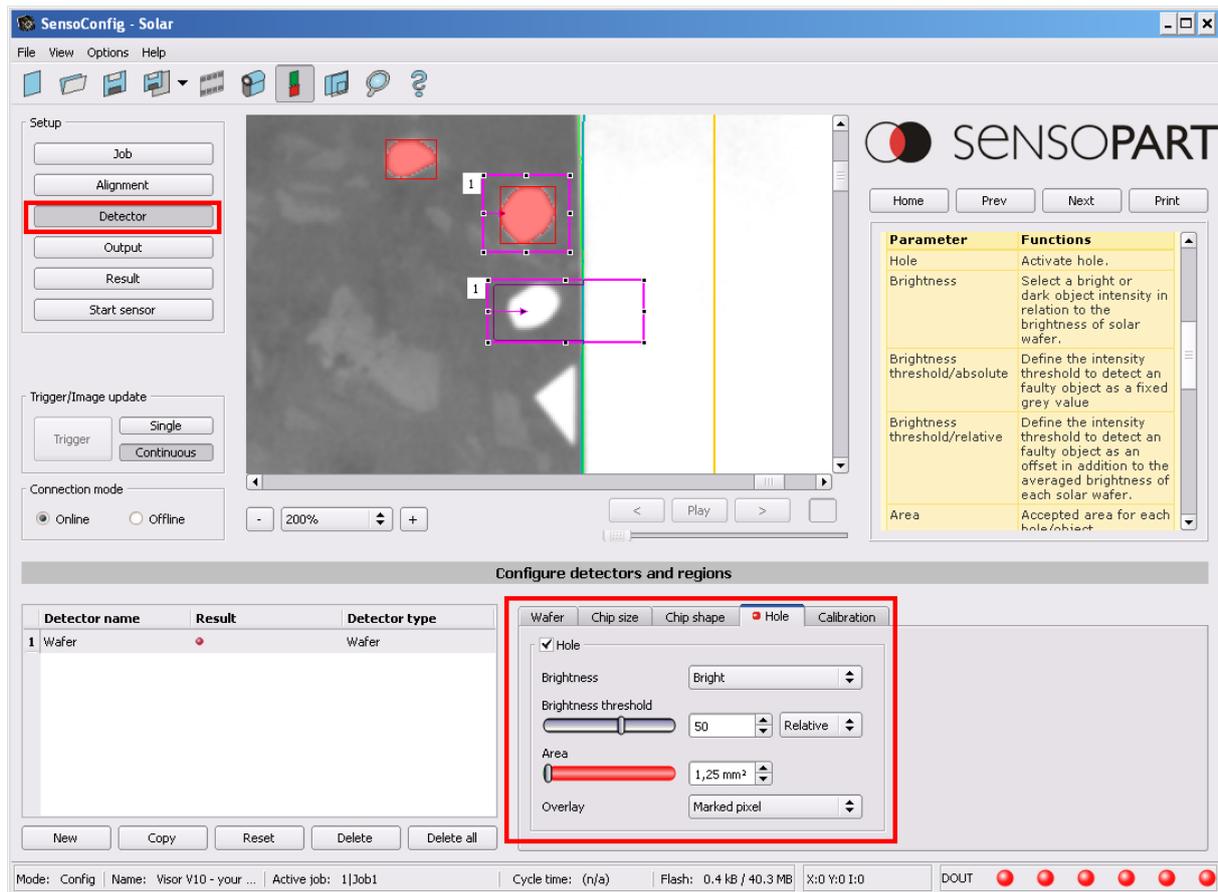
Depending on the different mounting position of your sensors and therefore different calibration factors of the two sensors all given positions and measurements have to be done in pixels.

### 5.3.7 Hole Tool

The *Hole* tool is very versatile to detect spots within the area of the wafer or cell, which are of special interest such as

- Holes formed during the manufacturing of the ingot or block
- Cracks
- Stains from a printing process
- Holes or inhomogeneities in the antireflective coating

In the following the usage of the *hole* tool and the mentioned applications will be described.



**Figure 42: Configuring the *Hole* detector**

The wafer detector determines the average grey level of the wafer. Referring to this level, which can be shifted by a value entered in *Brightness threshold*, deviations within the wafer/cell area can be detected. Select the *Brightness* of the spot of interest as *Bright* or *Dark*.

For test purposes the user may enter *Absolute* values – not related to the gray level of the wafer. To achieve sufficient stability of the tests, it is strongly recommended to use *Relative* thresholds only.

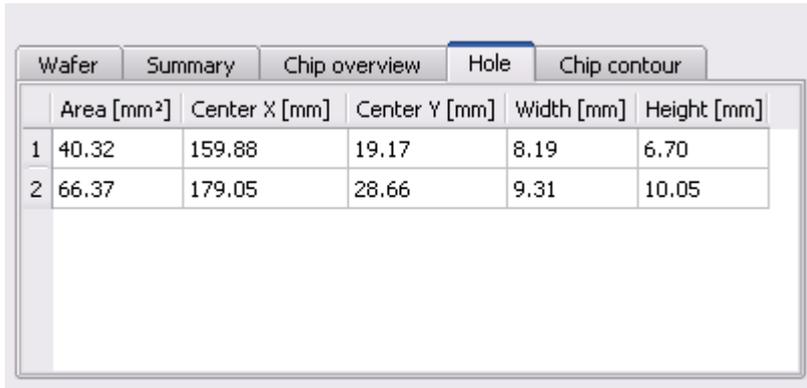
The default setting *Marked pixel* of *Overlay* makes all pixels meeting above criteria to be shown in red.

Adherent pixels (so-called blobs) which do not meet the *Area* criterion cause a FAIL and will be surrounded with a red rectangle – see 1<sup>st</sup> item above. In case 10 holes have been detected, the search for further holes is aborted.

*Blanking regions* affect the search for holes only in case they cover the wafer AND the surrounding. Blanking areas, which are completely inside the green square area are ignored – see 2<sup>nd</sup> and 3<sup>rd</sup> item above.

In case the *Expert setting* “*Filter wafer edge*” has been activated (not shown here) holes which are close to the wafer edge are ignored – see 4<sup>th</sup> item above.

All found holes exceeding the area limit are shown in the sub menu *Result* (press button *Result* as in *Figure 36*) in the tab *Hole*. They listed with their position and size (see *Figure 43*). The tab *Summary* provides the number of found holes.



	Area [mm <sup>2</sup> ]	Center X [mm]	Center Y [mm]	Width [mm]	Height [mm]
1	40.32	159.88	19.17	8.19	6.70
2	66.37	179.05	28.66	9.31	10.05

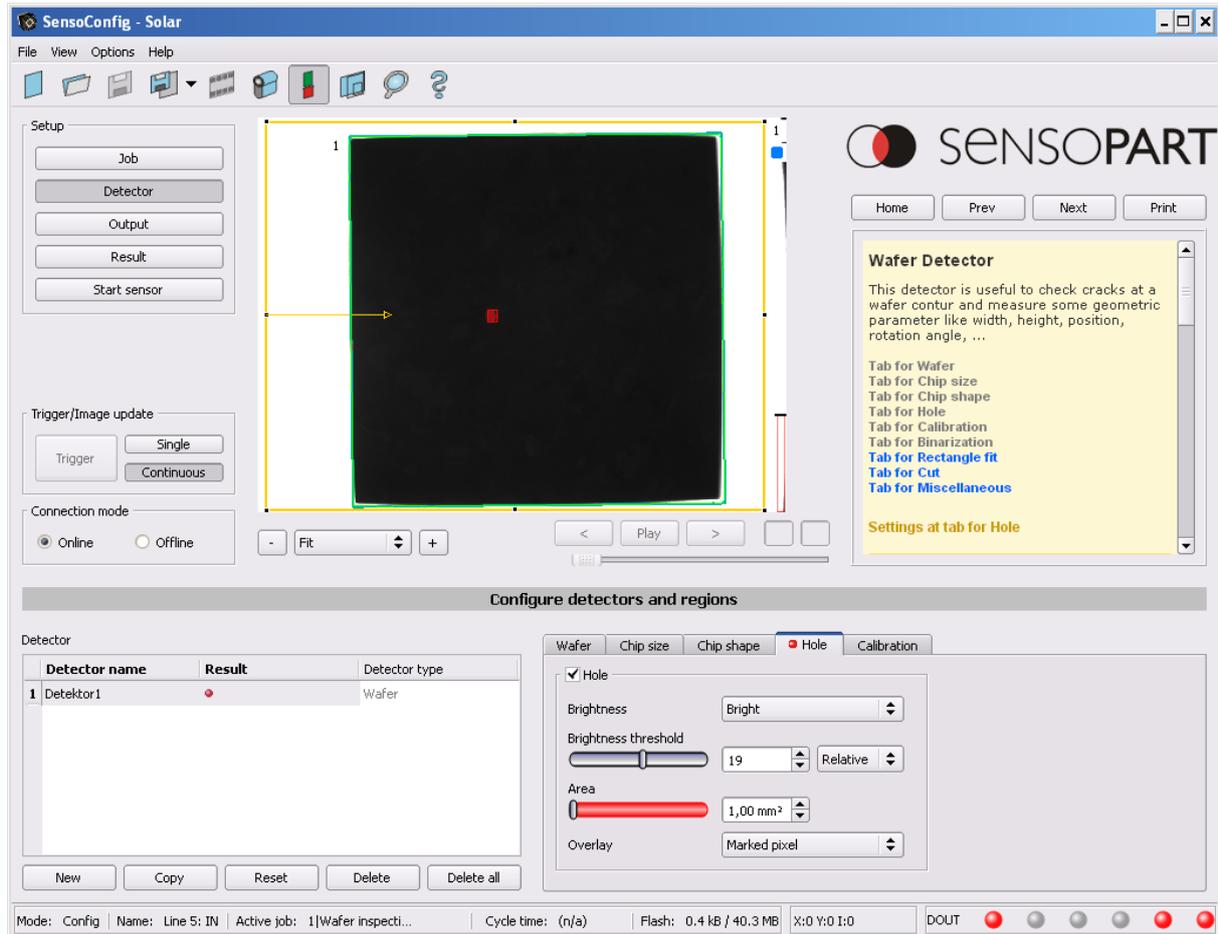
**Figure 43:** Tab *Hole* of the *Result* sub menu

### 5.3.7.1 Holes, Cracks and Stains

Holes formed during the manufacturing of the ingot or block can be observed using the back light shown in *Figure 9* in combination with the *hole* tool. The same setup should be used to detect cracks.

Moreover, this tool can be used for detecting the larger stains as residues from the printing process in a front light setup.

The brightness threshold has to be adjusted to observe the defect, which is then marked in red.



**Figure 44: Hole detection**

Using an active backlight holes and cracks can be detected down to 0.02 mm<sup>2</sup>. The average cycle time to perform this operation is 6 ms, largely independent of the wafer properties.

### 5.3.7.2 Checking the quality of the antireflective coating

The quality of the antireflective coating (ARC) of wafers can be checked from the sensor with the *hole* tool of a *wafer* detector. Visible defects of the ARC may be caused by the following origins:

- Dust particles of sizes of typ. 1 mm<sup>2</sup>
- Insufficient cleaning before the ARC process on spots of 100 mm<sup>2</sup> and more

To check the antireflective coating first create a *Wafer Detector* as described in section “5.3 Configuration of the “Detector” characteristics”. Then use the *hole* tool to detect areas with bad antireflective coatings and therefore a higher reflection. Choose in the tab *Hole* of the *Detector* sub menu the *Brightness* as *Bright*.

With *Brightness threshold* you choose the threshold between the good and the bad areas on your wafer surface. In typical applications, the default setting of 30 (relative), will lead you to good results. As known from the threshold settings before and in according to section “5.3 Configuration of the “Detector” characteristics”, it is very useful to check your setting on some test wafers.

A screenshot of a typical setting is shown in Figure 45.

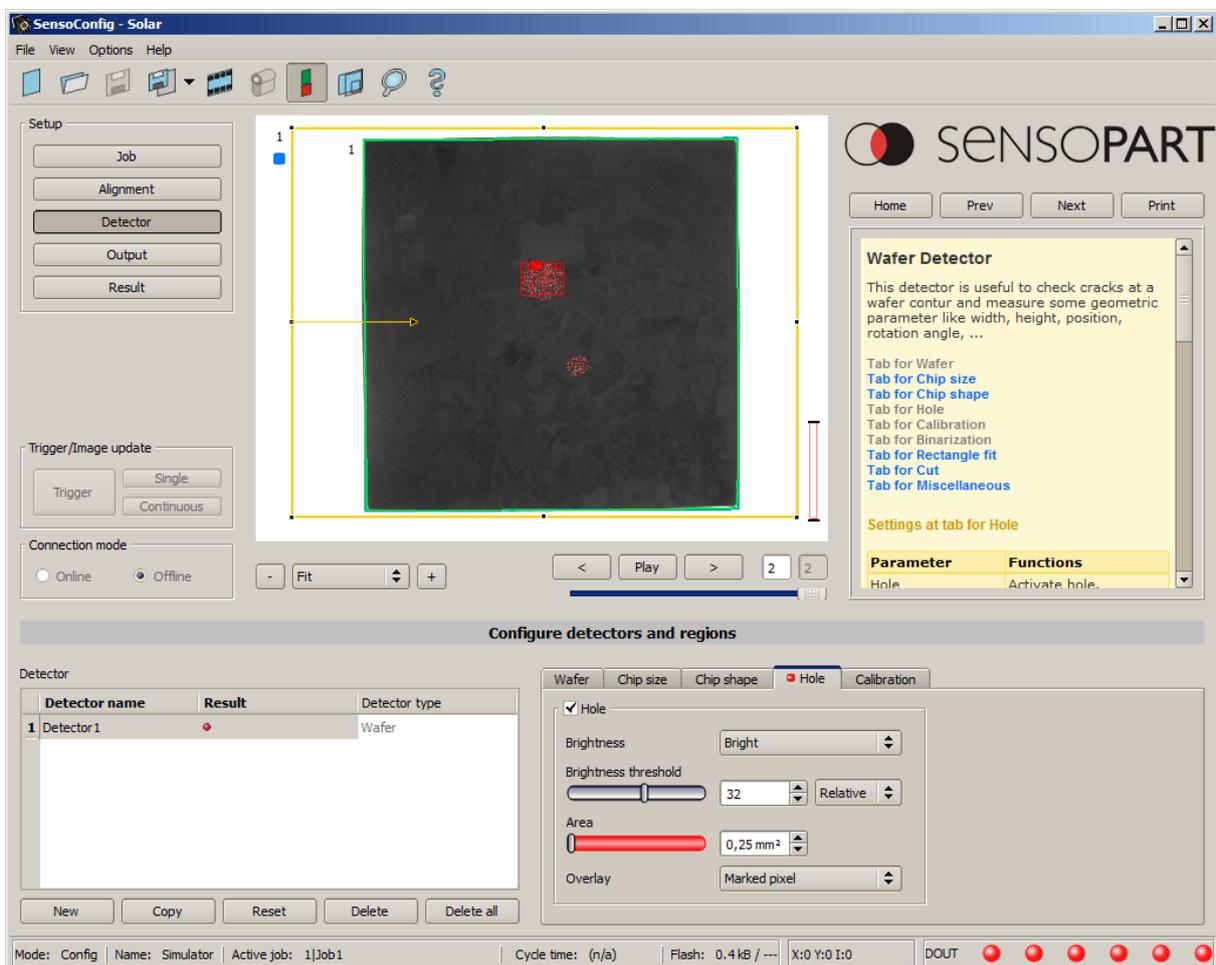


Figure 45: Example of a polysilicon wafer with an incomplete ARC due to insufficient cleaning

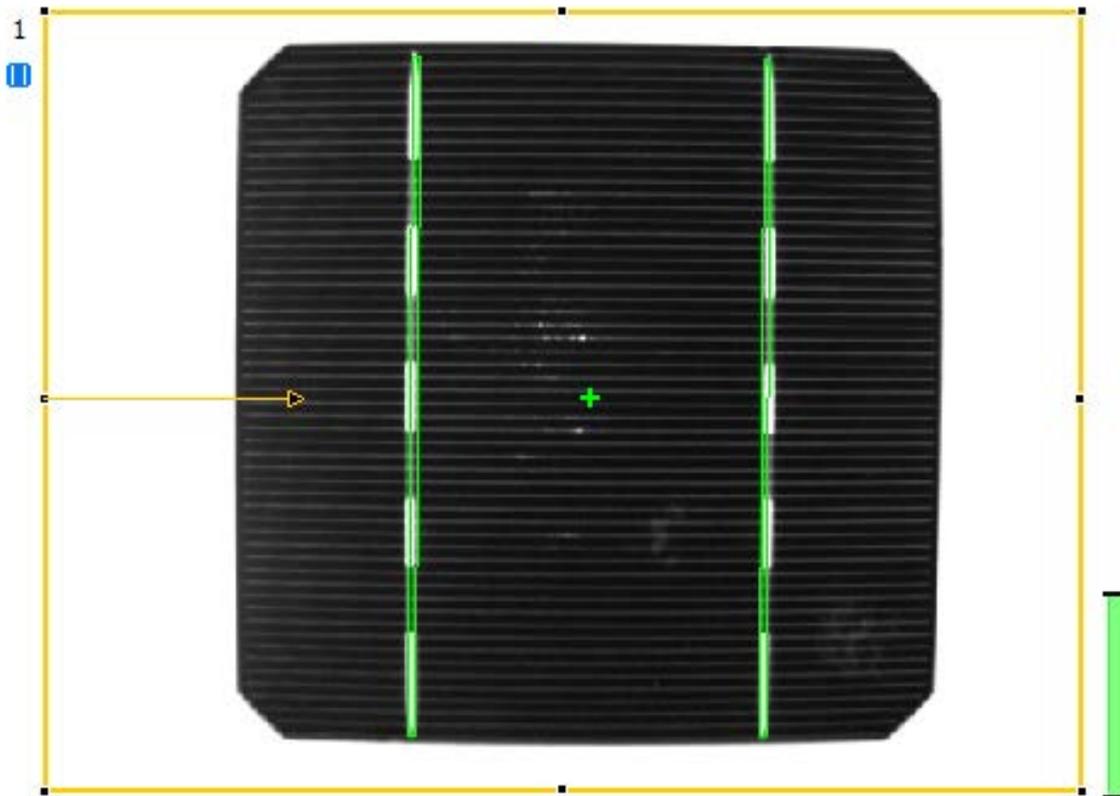


### 5.3.9 Busbar analysis

For several applications the position and type of busbar needs to be detected:

- Tabbers / stringers
- Electrical tests
- Print control
- Cell type identification

For this purpose the *Busbar detector* has been developed. It can be applied to solid busbars as well as to busbars comprising of pads as shown in Figure 47. Even busbars of MWT cells can be analysed.



**Figure 47: Analysing busbars of a pad cell**

To analyse the front side printing of a cell a front light illumination either by the internal LEDs or by a ring light should be applied. A white homogeneous background provides best results. Do not use an active backlight or a reflective foil when performing a busbar analysis.

To analyse cells with their busbars the following configurations may be applied.

- If a **homogeneous background** is applied, the *busbar* detector can be combined with a *wafer* detector subsequently analysing the same image acquired by one job.
- In case **no homogeneous background** can be provided, the *busbar* can still be detected due to the two detector concept. But a *wafer* detector may not be able to separate the cell from the machine parts. Thus, the job may comprise of just one *busbar* detector.
- To **optimize the illumination** for the different requirements of the wafer and *busbar* detector the two detectors can be distributed to two different jobs. This way even a switched backlight can be run in combination with the *wafer* detector without affecting the *busbar* detection. However, this approach requires a much higher cycle time and job switching by a PLC.

The easiest way to determine the *calibration factor* for *mm units* is to implement a *wafer* detector and copy the value to the clipboard.

To make use of the *Busbar* detector, a new *Detector* has to be created, which is described in section "5.3 Configuration of the "Detector" characteristics". Choose a "Busbar" detector (6<sup>th</sup> item in the list in Figure 37).

For calibration activate *mm units* on the tab calibration and paste the *calibration factor* determined by the *wafer* detector or other means into the busbar detector's control *calibration factor* and press *Apply*, see Figure 48. All settings of *calibration* including *distortion removal* should be identical for all *wafer* and *busbar* detectors.

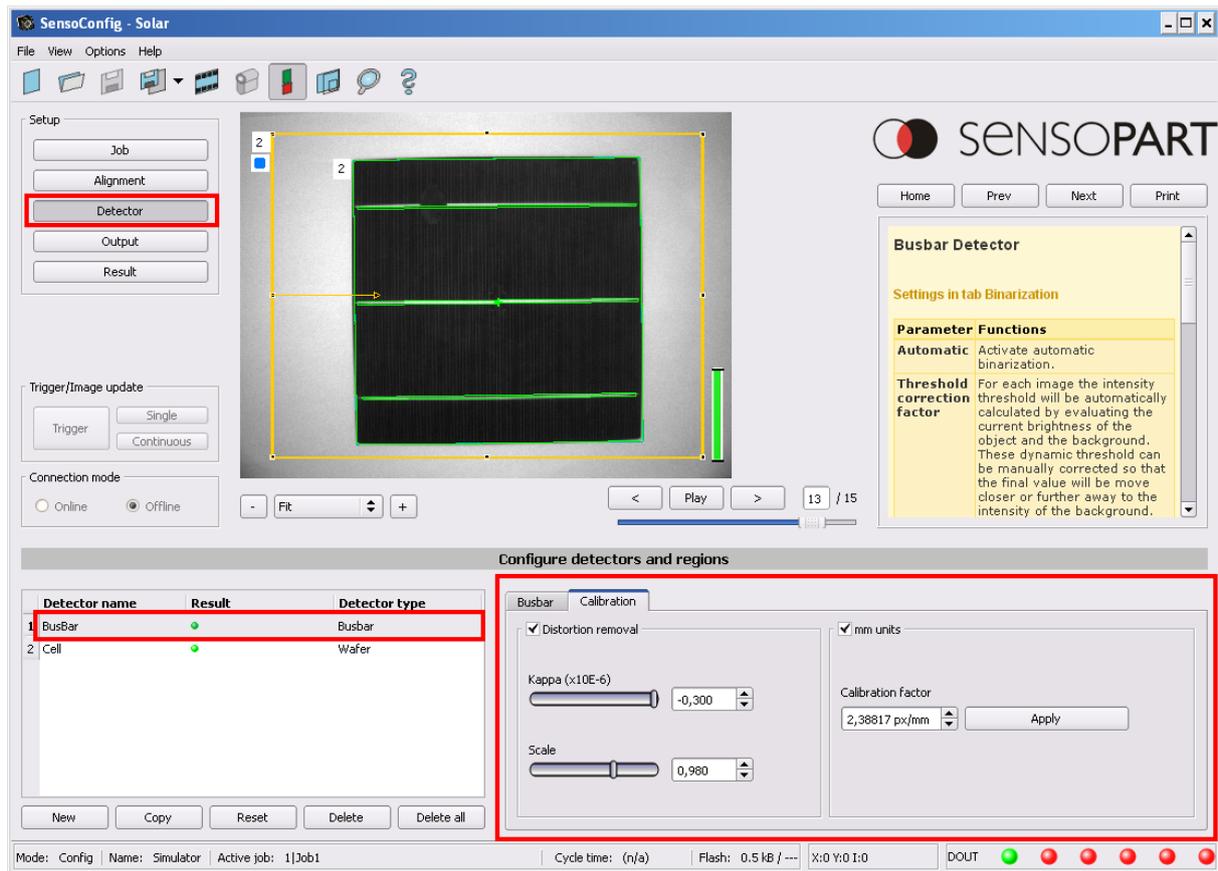
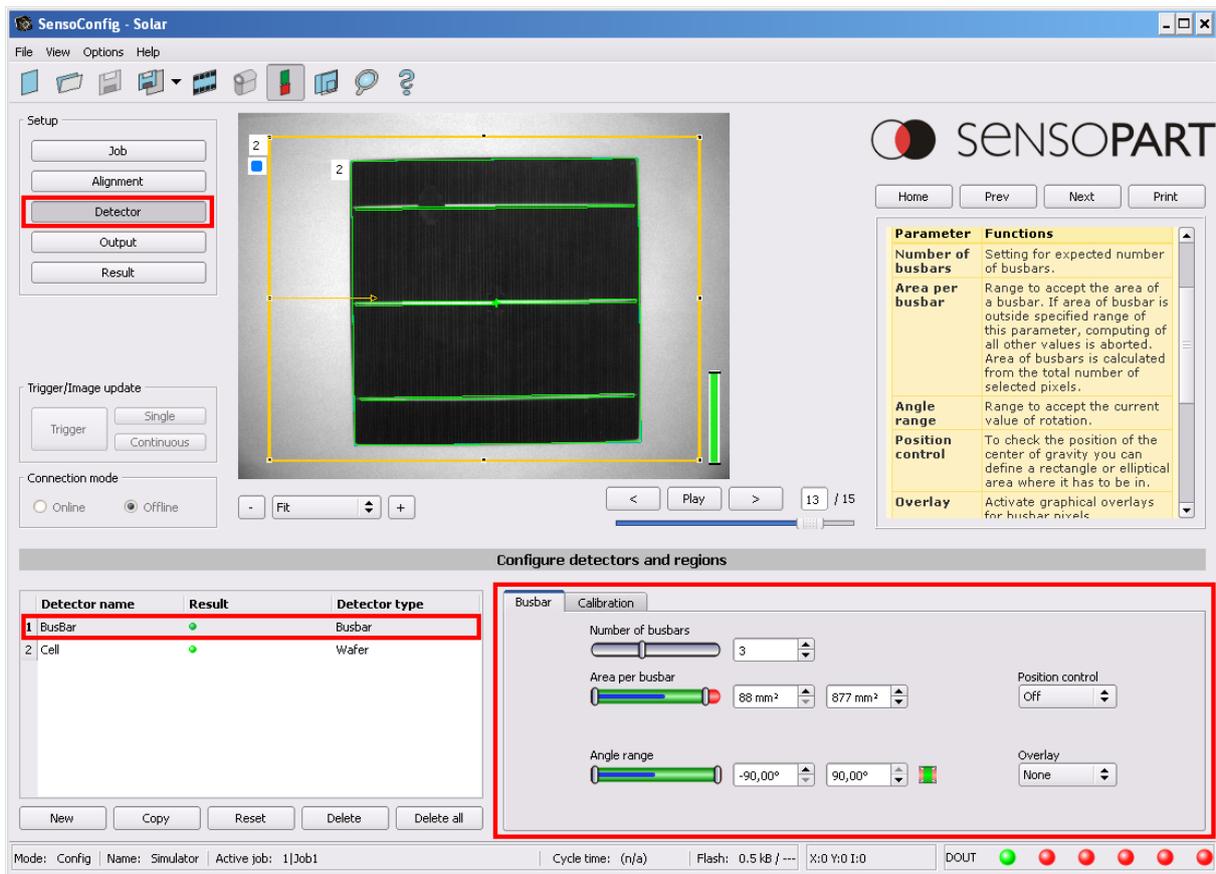


Figure 48: Calibration of the busbar detector

Then, switch to the tab *Busbar* to configure the *busbar* detection.



**Figure 49: Settings of the busbar detector**

The settings of the Busbar Detector are done with a few clicks. First, the yellow region of interest (ROI) has to be adjusted in the well-known manner (described in section 5.3 Configuration of the "Detector" characteristics).

The *number of busbars* has to be set with the slider to the value corresponding to the analysed cell. Any deviation between setting and observed number of busbars will lead to a FAIL.

With *Area per busbar* the area of each busbar is compared to the limits. The actual measured area is shown in the slider as a blue line, see *Figure 49*: . If the area of the busbars is not in the set range, this will cause a FAIL.

With the slider *Angle range* the angle of the busbars in respect to the coordinate system of the sensor can be checked.

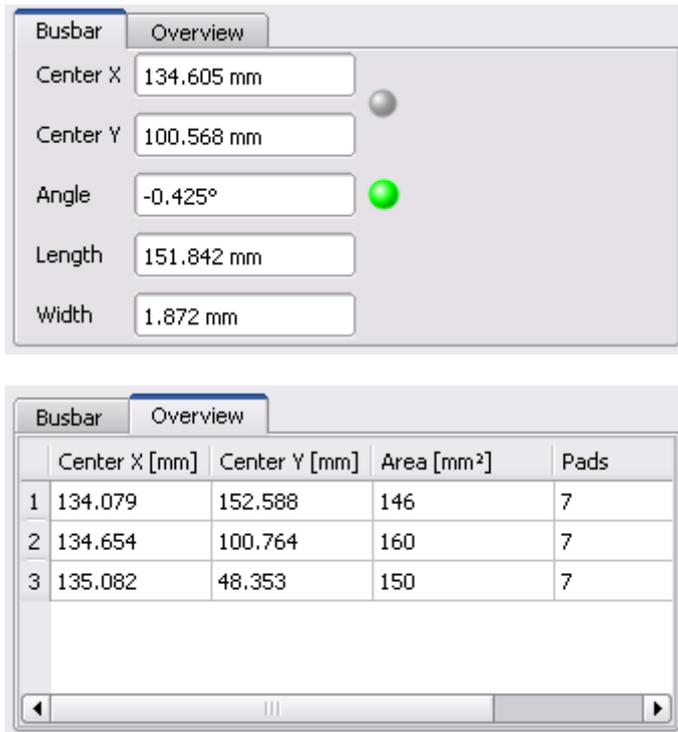
With the *Position control* the measured position of the gravity centre of the busbars will be checked. This is done with two possible shapes of allowed areas, a rectangle or an ellipse. They appear as blue areas on the screen. The size and position are changed similarly to those of the ROI.

Activating the *Overlay* by switching to *Busbar pixel* will lead to a colouring all pixel which are considered to be part of a busbar.

Please note, that the function of the busbar detection has been successfully verified on various known cell designs. In case of very conventional cells like ones with more busbars than pads per busbar the sensor may not operate as expected.

After a successful detection of the busbars, each busbar will be surrounded by a green computed rectangle. In case of an active *distortion removal* the rectangle and the image may apparently deviate despite of a good fit. The center of all busbars is always indicated as a green cross. To compare it to the center of the cell activate the *position control* of the *wafer* detector and find the wafer center as a blue cross as shown in Figure 34.

The results of the *Busbar* detector are shown in the *Result* window after selecting this detector in the list. In the tab *Busbar* from the Result window there are the main characteristics of the busbars: The centre of gravity, the angle of the set of busbars and their width and length. In the "*Figure 50: Result tabs of the Busbar Detector*" the dot right of the centre values is grey, because the *Position control* feature is not activated. The angle of the Busbars is in the acceptance range of therefore the dot right to it is green. All FAILs will result in a red coloured dot.



**Figure 50:** Result tabs of the *Busbar* Detector

The values of the individual busbars are shown in the tab *Overview*. These values include the centre, the area and the number of *Pads*. Since some Busbars are not printed as straight line (to reduce consumption of expensive silver paste) they are printed as a dashed line with some pads as contact to the ribbons. For this purpose the *number of Pads* detected is shown. Interrupted busbars are indicated by a higher number of pads.

As *area* all pixels belonging to pads are considered, but not the spacing in between them.

### 5.3.9.1 Cell analysis

Cells of different designs can be distinguished by setting up a job file for each of them and check for the following properties:

Cell types			
Cell property	Distinguished types	Detector	Detected parameter
Size	5 and 6 inch cells	Wafer	Height
Chamfer	Mono and multicrystalline Chamfers of different sizes	Wafer	Area
Color	Reflectivity	Brightness	Score
Number of busbars	2 and 3 busbar cells	Busbar	Number of busbars
Busbar spacing	75 mm / 78 mm / 105 mm cells	Busbar	Centers of each busbar
Number of pads	Standard busbars / pad cells	Busbar	Number of pads
Busbar width	Cell design	Busbar	Busbar width

Several job files can be loaded on one camera of the *Advanced* product line. Via an Ethernet command the job for execution can be selected.

*The quality of the following cell properties can be tested:*

Quality criteria for cells		
Quality criterion	Detector	Detected parameter
Chip	Wafer	Chip size Chip shape Height
Hole	Wafer	Hole
Crack	Wafer	Hole
Stain	Wafer	Hole
Busbar interruption	Busbar	Number of pads
Sunny side up	Gray level	Score

For further parameters please contact SensoPart technical support.

### 5.3.9.2 Stringers

To make sure that only cells of the same appearance and design are combined in a string a job describing a certain cell type and running relevant quality test has to be set up. Obviously, the center and orientation of the busbar and cell has to become part of the telegram as well.

Usually, stringers require a lengthy telegram interfacing them to a PLC. To make sure, this telegram definition is identical for all cell test recipes, it is recommended

- to define a master job with a master telegram tested in conjunction with the PLC.
- move to section *Job*.
- do a right click on this master job to get a context menu
- use "copy parameters" for telegram items only to transfer these to a second job.

Any differences in telegrams or interfaces will be indicated by a message "Inconsistent telegram" when starting the sensor.

It is recommended to use two fiducials to ensure a long-term stability of the position detection.

## 5.4 Adjustment of the needed I/Os via "Output"

The configuration of the in-built digital I/Os are done under *I/O mapping*. The sensor includes four user configurable I/Os and the data interfaces. Depending on your machine configuration, different settings are needed. The sensor is able to communicate with the PLC of your machine via digital I/Os, RS 232, RS 422, Ethernet and Ethernet/IP. The general settings of all interfaces are done with the *Interfaces* tab. With *Timing* the trigger delay and other delay times can be configured. The definition of the messages sent via the data interfaces can be done with the *Telegram* tab.

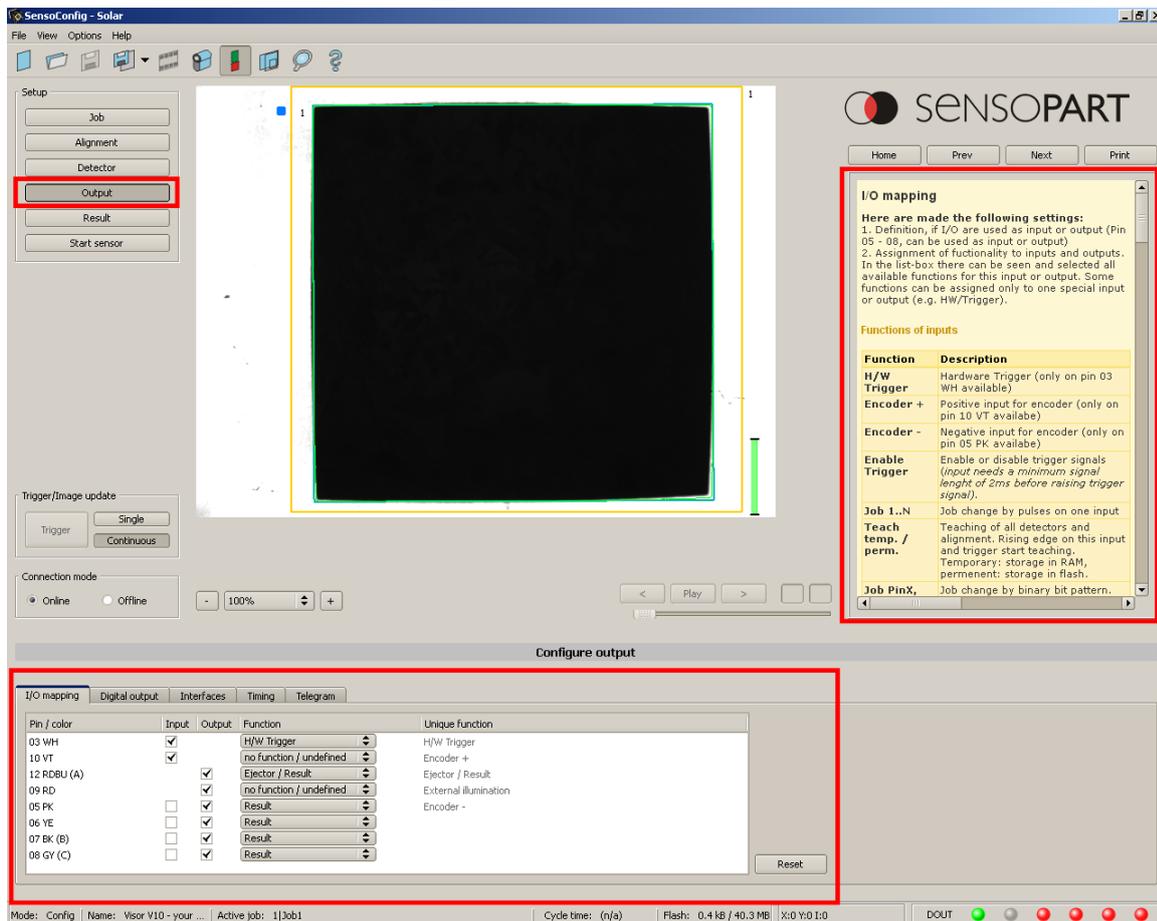


Figure 51: Start window to configure the Outputs

### 5.4.1. I/O mapping

With the *I/O mapping* you can choose which digital In- or Outputs you use. The pinning has been described in section "4.1.2 Electrical connection" respectively in *Figure 14*. The digital I/Os pins 5-8 can be configured either as input or as output. In *Figure 51* a screenshot of the start window is shown.

In the advanced version, pin 10 can be used as positive encoder input. Optionally on pin 5 a negative encoder input is available.

To configure an I/O as Input or Output use the check boxes. The available functions are described in the in Online help of *SensoConfig* on the right.

### 5.4.2 Digital output

With the *Digital output* tab you can define, which results are attributed to which pins. In *Figure 52* an example is shown. On pin 5 is the result of detector 1 (a grey level detector), on pin 6 the inverted result of detector 2 (a wafer detector), on pin 7 the result of detector 2, on pin 8 the inverted result of detector 2. On pin 9 is the signal for the external illumination and on pin 12 the result of both detectors. The targeted effect of the Output signal can be chosen, just by using the drop down list. When you use the *Extended* option on the left, a logical expression can be written in the last column *Logical expression* to use a logical expression of the result of different detectors. Some examples to write logical expressions are given in the in built help on the right.

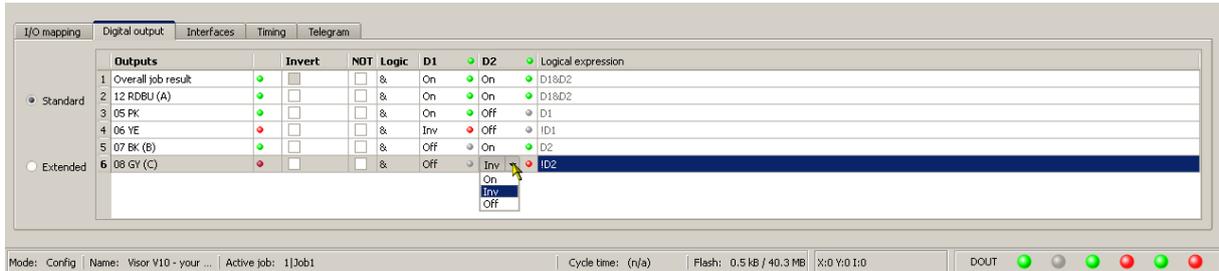


Figure 52: Tab Digital Output of the Output sub menu

### 5.4.3. Interfaces

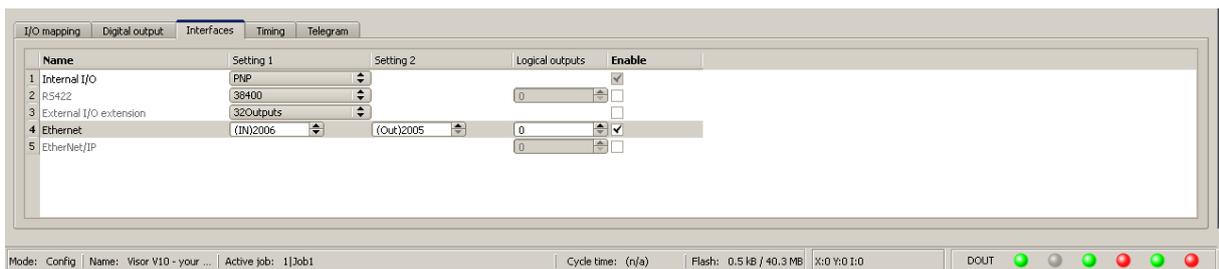


Figure 53: Tab Interfaces of the Output sub menu

Via the *Interfaces* you are able to configure characteristics of the interfaces. The settings are done by using the drop down lists just with a few clicks. First, you have to enable the needed interface, then you can choose the useful settings via the *Setting 1/2* column. The Internal I/O can be set as NPN or as PNP Output, in the NPN configuration a external Pull-up-Resistor is needed on the Inputs (*Figure 54*).

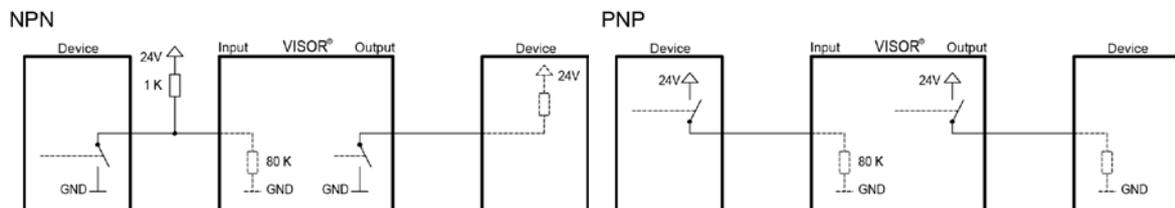


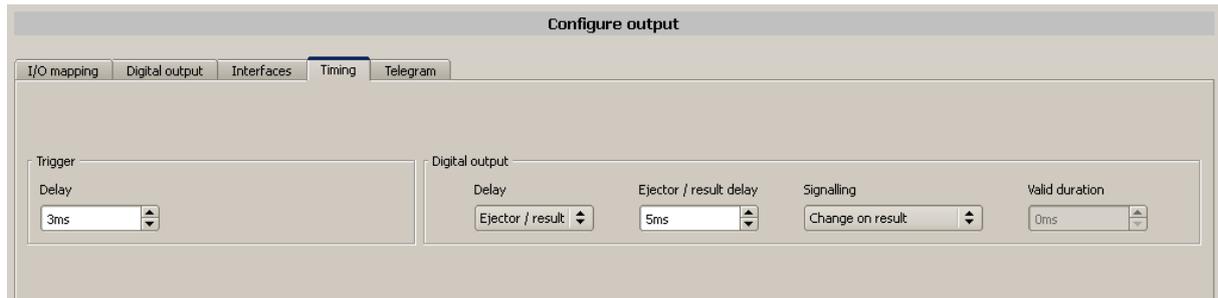
Figure 54: Example of the external electrical connection of the *Internal I/Os*

For the RS 422 interface the data transfer rate have to be chosen, default is 38400. When you use an *External I/O extension*, here you have to tell the sensor which kind of external extension you use. When using the Ethernet protocol you can choose which port is your In- or Output. The number of logical outputs can be changed with the spin boxes.

#### 5.4.4. Timing

As described before it's useful to trigger the sensor to provide a synchronous image acquisition. The sensor may also provide a delay between the trigger signal and the image acquisition. There are two units that can be used to provide the delay: The typical way will be time delay where the image acquisition starts some milliseconds after the trigger signal. The second way provides a high position accuracy even on conveyor belts with varying speed by using an encoder input signal (available only in the *Advanced* version).

In the *Standard* version of the sensor the time delay is determined with the *Timing* tab. With *Trigger Delay* the time between trigger and the start of the image recording is determined. The time delay between the trigger signal and the change of the output signals depending on the result of the *Detector* result is determined with the *Digital Output* tab. All delays are given in milliseconds.



**Figure 55: Tab Timing of the Output sub menu**

After assigning an encoder pin the delay will then be measured in encoder steps. For further information see the online help on the right of SensoConfig.

#### 5.4.5. Telegram

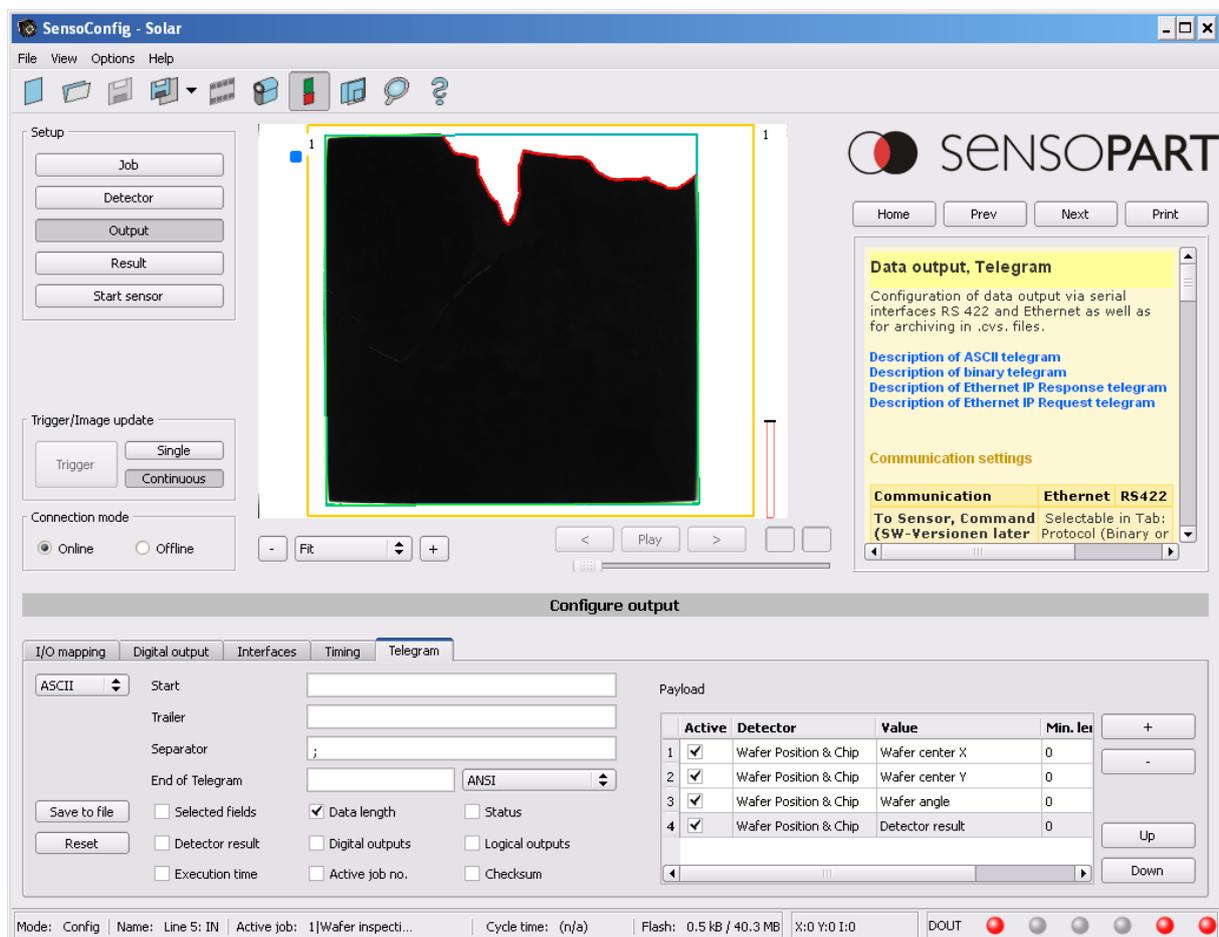
A telegram can be setup easily by a few clicks to meet the standard defined by the PLC.

At first, ensure that the respective ports are activated. In case values like positions are to be transmitted, in the section *Output / Interfaces* the *Ethernet* interface becomes *Enabled*. Alternatively, serial links or the field bus *Ethernet / IP* may be enabled. Digital outputs to distinguish between PASS and FAIL parts do not require a definition of a telegram. It is recommended not to change other parameters than the enabling of the interfaces (see *Figure 53*).

Secondly, an ASCII or binary telegram is composed according to the requirement of the PLC by few further clicks.

The settings done in the following screenshot leads to a ASCII telegram containing:

- **Data length:** e.g. 22
  - Separator: ;
- **Wafer center X position in  $\mu\text{m}$ :** e.g. 105870
  - Separator: ;
- **Wafer center Y position in  $\mu\text{m}$ :** e.g. 82198
  - Separator: ;
- **Wafer angle in Millidegrees:** e.g. 232
  - Separator: ;
- **Result of chip test:** Either P for PASS or F for FAIL
  - Separator: ;



**Figure 56: Definition of a typical ASCII telegram**

To add new results to the telegram click on the right on the "+" button. A new line in the *Payload* window will be shown. First ensure, that the check box *Active* is checked, then choose your *Detector* in the next drop down box. In the drop down menu *Value* you can choose the result which is given out.

In addition Figure 57 shows the *telegram* definition of a Busbar Detector.

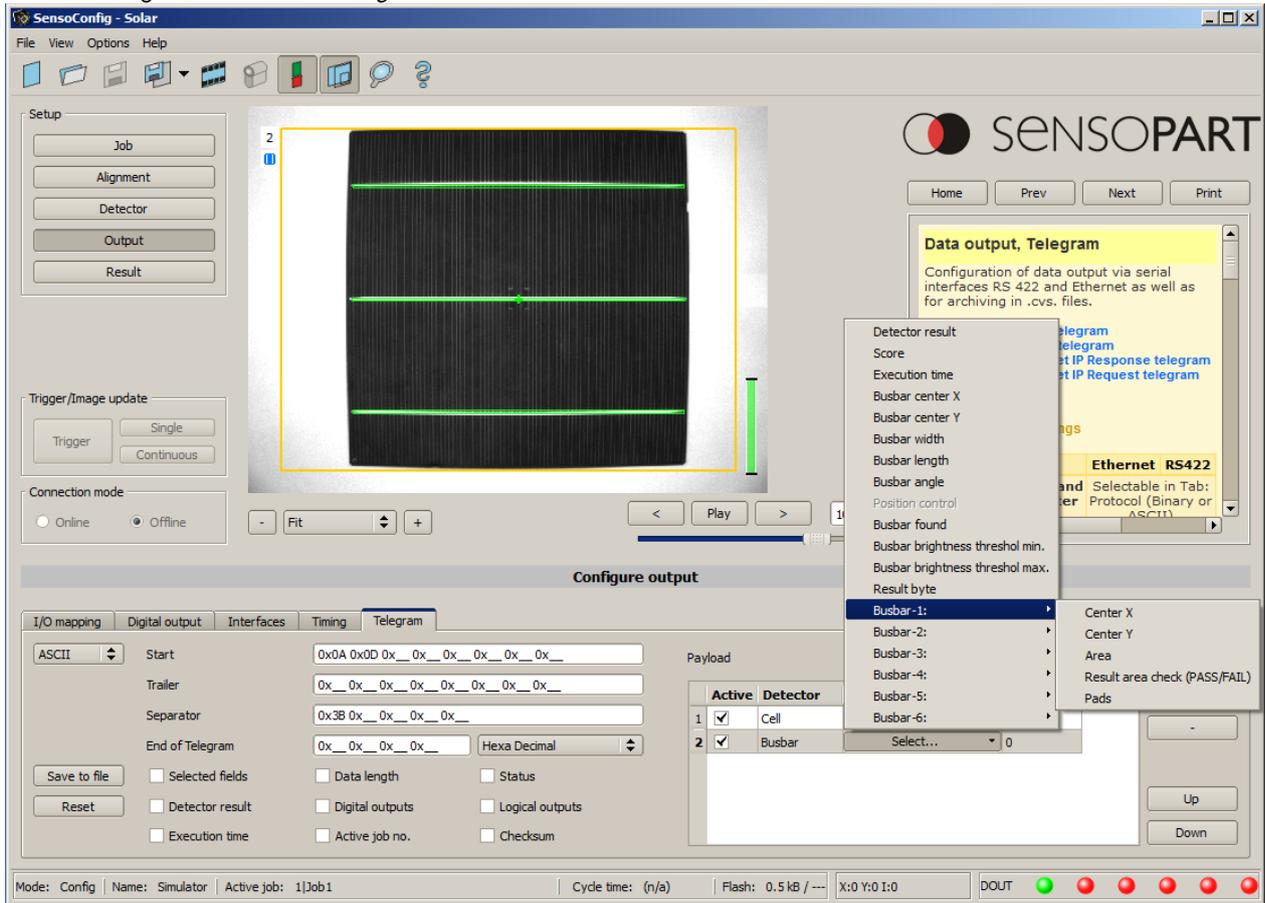


Figure 57: Telegram definition of a Busbar Detector.

Once the sensor has been started, it autonomously sends a telegram for each image taken. The example above is compliant to a tool logging the telegrams into a .txt file, which is described in section "

*7.1.2 Data log*.

## *5.5 Starting the sensor*

Now all settings are done, their results checked you are now able to start the sensor it will then run autonomously. To start the sensor press the *Start* button as described at the beginning of section "*5 Software configuration*". All needed settings will be stored now on the sensor, until they are overwritten with new settings. It may be useful to save the actual *Job*-file on your PC as a back-up or to use it in similar machine configuration as described in section

## 6 Cycle time

This section summarizes the cycle times which are to be expected under typical conditions. Obviously, the cycle time depends on the content of the image, which may deviate from the setups used here. Typically, the 6 mm cameras run with a cycle time of 72 ms, whereas 12 mm and C-Mount cameras require just 57ms for the same task.

<u>Cycle time</u>	V10 SO*	Condition	Typical set-up Cell Handling	Typical set-up Stringer
Image acquisition & wafer position	43 ms	Good Wafer	43 ms	43 ms
Further wafer detector	+22 ms	Good Wafer		
Wafer / Blanking region	+ 2 ms	4 Regions, size dependent		
Wafer / Area	+10 ms			
Calibration / Distortion compensation	+18 ms			+18 ms
Chip size	+11 to +24 ms	Good wafer - Fragments	+11 ms	+11 ms
Chip shape	+32 to +48 ms	Good wafer - Fragments		
Hole	+ 6 ms			
Grey level detector: Sunny side up/down	+ 1 ms			
Position of 2 Fiducials	+ 6 ms			+ 6 ms
Image acquisition & busbar position	+72 to +90 ms	2-3 Busbars / straight, pads		+ 72 ms
			<b>Total: 72 ms</b>	<b>Total: 150 ms</b>

\*Cameras manufactured before September 2012 and updated to this firmware show different cycle times.

Figure 58: Cycle time of the offered tools. The 'Typical setup' refers to a V10-SO with 6 mm lenses.

In case of severe disturbances of the image, e.g. when there is no wafer but a machine background present or a hand of the operator is exposed to the camera, the cycle time may deviate significantly from the above observations. To cope with such situations in a line which constantly feeds wafers, the *Job / cycle time / max. cycle time* should be activated and set to a value which is required for an undisturbed line operation. Thus, the image analysis will be aborted after this duration and the result will be a FAIL.

## 7 VISOR® related tools

### 7.1. Software

#### 7.1.1 SensoView

With the VISOR® software package comes a tool dedicated to be used by operators. Unlike *SensoConfig* it can be used during running production to show the actual images, results and statistics. The operator cannot change parameters with this software.

*SensoView* is started by selecting a camera with *SensoFind* and pressing the *View* button. The first pages shows the results as described previously for *SensoConfig*.

In case of several jobs and detectors being uploaded to the camera, the respective item can be selected within *SensoView*.

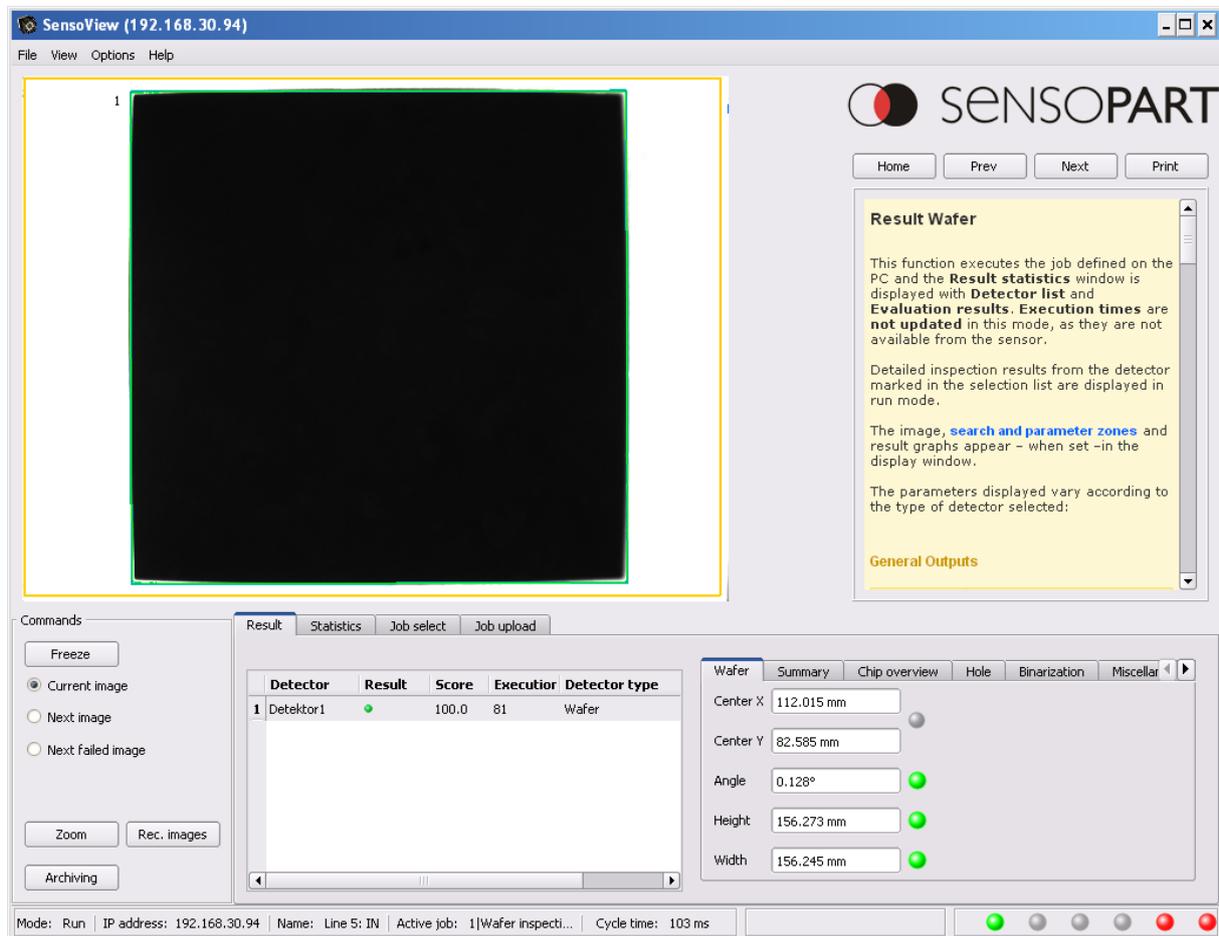


Figure 59: Results shown to the operator using *SensoView*

In a very convenient way, the *Current image*, the *Next image* or the *Next failed images* can be saved by simply pressing the *Archiving* button. To avoid unintended usage, this function must have been enabled previously by *SensoConfig / Job / Image transmission / SensoView*. The path of the archive can be defined within *SensoView / File / Result archiving ...*

The archived images can be analysed in offline simulation with varied detector settings. Thus, the user can optimize the line without running the line during the optimization.

The statistics of PASS and FAIL devices is shown on a further tab. Additionally, the execution time is shown.

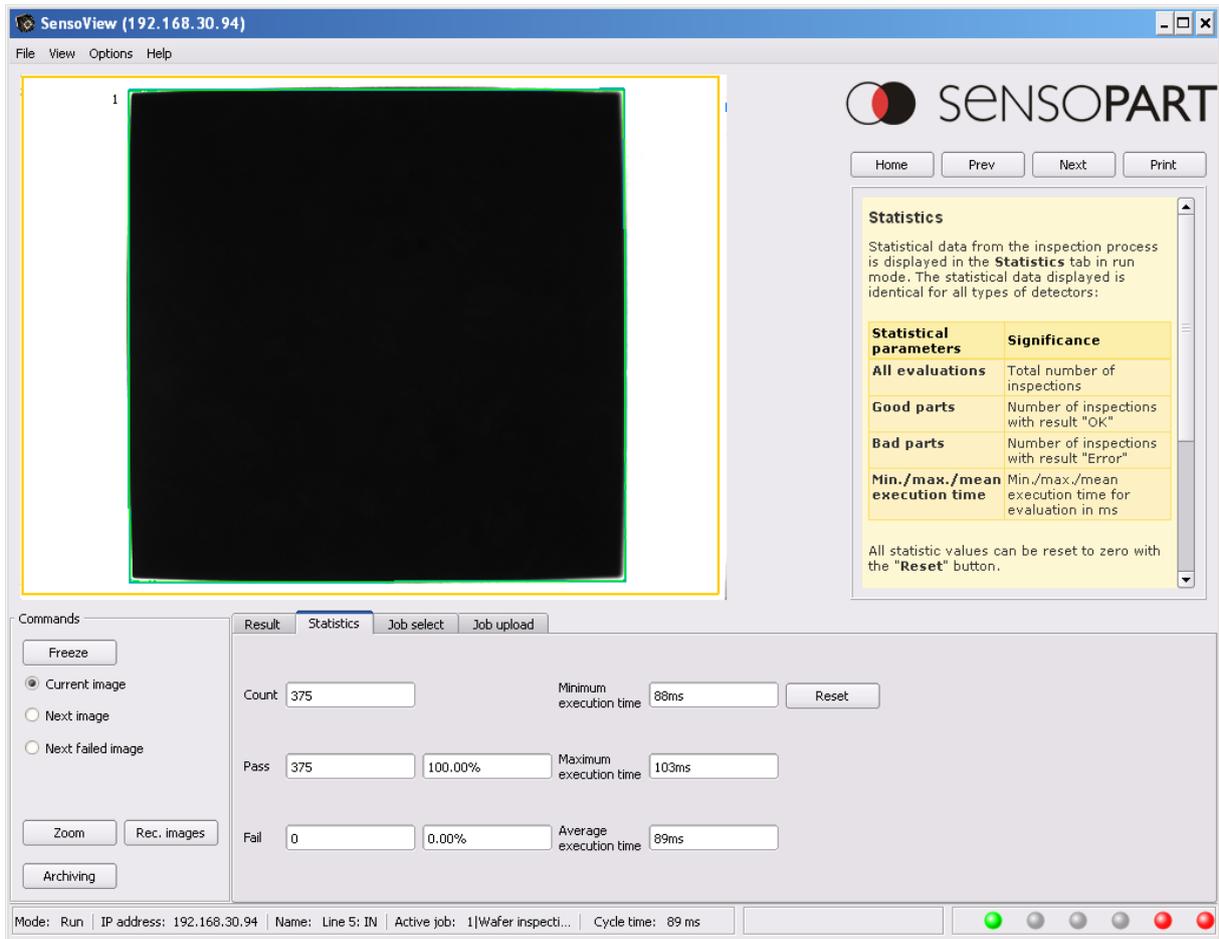


Figure 60: Statistics shown to the operator using *SensoView*

For further details see VISOR® user manual.

### 7.1.2 Data log

The data of the sensor's telegram is usually read out by the PLC. To test the precision of the VISOR® sensors and the setup in the individual machine it may be useful to read-out the telegram sent from the sensor. This can be done with the freeware program Hercules available from the Internet:

[http://new.hwg.cz/download/sw/version/hercules\\_3-2-5.exe](http://new.hwg.cz/download/sw/version/hercules_3-2-5.exe)

To get a telegram for the program "Hercules" first enable "Ethernet" in the section *Output* / tab *Interfaces*. Second, in *Output* / tab *Telegram* the following settings led to a telegram with a new line after each data set / telegram (LineFeed = 0x0A, Carriage Return = 0x0D) .

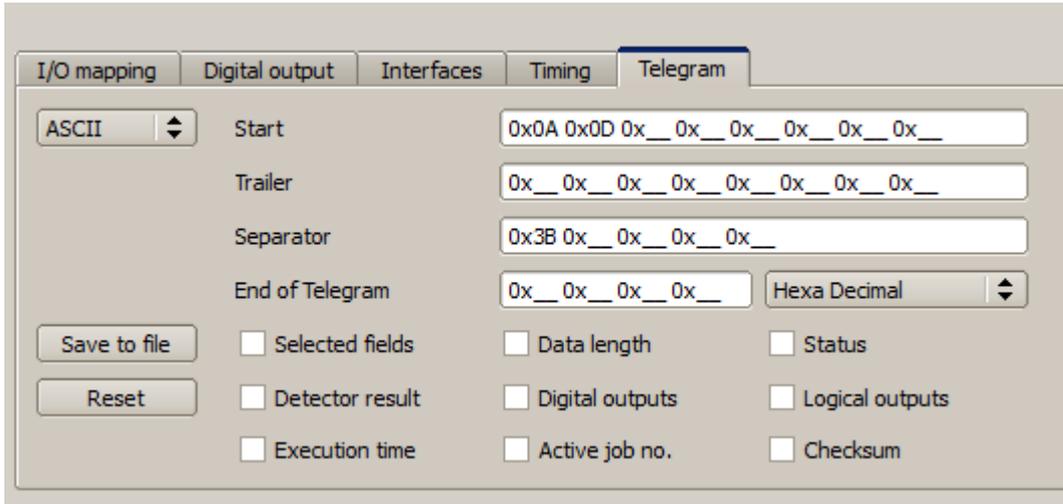


Figure 61: Definition of an ASCII telegram to create a log file, for Excel® import.

To receive the date, open the Hercules tool, turn to the tab “TCP Client” and enter the IP address of the sensor which runs autonomously, define the Port as 2005 and *connect* to it by pressing the highlighted button. With the context menu of the Hercules tool the data can be submitted to a log file.

A typical telegram shown with the Hercules software is given here.

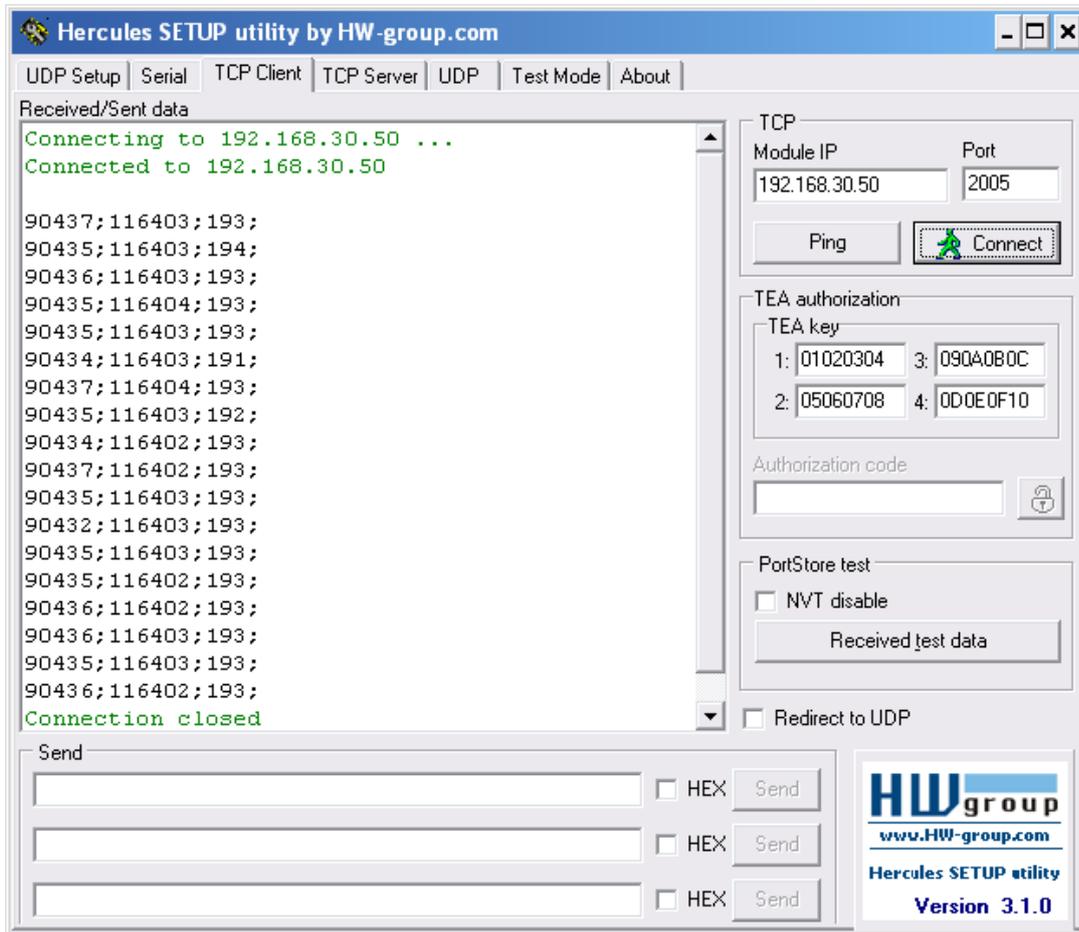


Figure 62: Receiving date from the VISOR® with the Hercules tool via Ethernet.

## 8 Related products

The most important products for the applications shown above are listed here. An actual and complete overview is offered by the product finder on our homepage.

<b>VISOR V10 Solar sensor</b>		
<b>Ordering code</b>	<b>Type</b>	<b>Description</b>
<b>Solar Standard camera</b>		
535-91049	V10-SO-S1-W6	VISOR V10 Solar sensor, Standard, max. 2 jobs with 32 detectors, for wafer inspection, 4 types of detectors, focal length 6mm, white LEDs, 8 IO channels, Ethernet, EtherNet/IP
<b>Solar Advanced cameras</b>		
535-91051	V10-SO-A1-W6	VISOR V10 Solar sensor, Advanced, unlimited number of jobs and detectors, alignment, for wafer inspection, busbar detection, 6 types of detectors, focal length 6mm, white LEDs, 10 IO channels, encoder input, interface to IO-Box, RS422, RS232, Ethernet, EtherNet/IP
535-91053	V10-SO-A1-I6	VISOR V10 Solar sensor, Advanced, unlimited number of jobs and detectors, alignment, for wafer inspection, busbar detection, 6 types of detectors, focal length 6mm, white LEDs, 10 IO channels, encoder input, interface to IO-Box, RS422, RS232, Ethernet, EtherNet/IP
535-91052	V10-SO-A1-W12	VISOR V10 Solar sensor, Advanced, unlimited number of jobs and detectors, alignment, for wafer inspection, busbar detection, 6 types of detectors, focal length 12mm, white LEDs, 10 IO channels, encoder input, interface to IO-Box, RS422, RS232, Ethernet, EtherNet/IP
535-91054	V10-SO-A1-I12	VISOR V10 Solar sensor, Advanced, unlimited number of jobs and detectors, alignment, for wafer inspection, busbar detection, 6 types of detectors, focal length 12mm, infrared LEDs, 10 IO channels, encoder input, interface to IO-Box, RS422, RS232, Ethernet, EtherNet/IP
535-91050	V10-SO-A1-C	VISOR V10 Solar sensor, Advanced, unlimited number of jobs and detectors, alignment, for wafer inspection, busbar detection, 6 types of detectors, C-Mount, 10 IO channels, encoder input, interface to IO-Box, RS422, RS232, Ethernet, EtherNet/IP
<b>Power and I/O cables</b>		
902-51801	C L12FG-S-2m-PUR	Power - I/O, Cable, 2 m, M12 / 12 pole, Straight Connector, shielded
902-51796	C L12FG-S-5m-PUR	Power - I/O, Cable, 5 m, M12 / 12 pole, Straight Connector, shielded
902-51797	C L12FG-S-10m-PUR	Power - I/O, Cable, 10 m, M12 / 12 pole, Straight Connector, shielded
902-51798	C L12FW-S-2m-PUR	Power - I/O, Cable, 2 m, M12 / 12 pole, Angled Connector, shielded
902-51799	C L12FW-S-5m-PUR	Power - I/O, Cable, 5 m, M12 / 12 pole, Angled Connector, shielded
902-51800	C L12FW-S-10m-PUR	Power - I/O, Cable, 10m, M12 / 12 pole, Angled Connector, shielded
<b>Ethernet cables</b>		
902-51754	CI L4MG / RJ45G-GS-3m-PUR	Ethernet, cable, 3m, M12, Straight Connector, 4pole / RJ45 shielded
902-51782	CI L4MG / RJ45G-GS-5m-PUR	Ethernet, cable, 5m, M12, Straight Connector, 4pole / RJ45 shielded
902-51784	CI L4MG / RJ45G-GS-10m-PUR	Ethernet, cable, 10m, M12, Straight Connector, 4pole / RJ45 shielded
902-51786	CI L4MW / RJ45G-SG-3m-PUR	Ethernet, cable, 3m, M12, Angled Connector, 4pole / RJ45 shielded
902-51788	CI L4MW / RJ45G-SG-5m-PUR	Ethernet, cable, 5m, M12, Angled Connector, 4pole / RJ45 shielded
902-51790	CI L4MW / RJ45G-SG-10m-PUR	Ethernet, cable, 10m, M12, Angled Connector, 4pole / RJ45 shielded
<b>Data cables (serial link)</b>		
902-51813	CI L5FG-S-2m-PUR	Datatable, 2m, M12 / 5 pole, Straight
902-51814	CI L5FG-S-5m-PUR	Datatable, 5m M12 / 5 pole, Straight
902-51815	CI L5FG-S-10m-PUR	Datatable, 10m, M12 / 5 pole, Straight
902-51816	CI L5FV-S-2m-PUR	Datatable, 2m, M12 / 5 pole, Angled
902-51817	CI L5FV-S-5m-PUR	Datatable, 5m M12 / 5 pole, Angled
902-51818	CI L5FV-S-10m-PUR	Datatable, 10m M12 / 5 pole, Angled
<b>Converters</b>		
533-11017	K2-ADE-TB	Converter RS232 - RS 485 / 422
901-05097	CUSB-RS232-2m	Interface cable, incl CD Rom, 2m - USB to RS 232
902-51735	AS S7/B1 D9F-D9F	Anybus Communicator - Profibus

<b>VISOR V10 Solar sensor</b>		
<b>Ordering code</b>	<b>Type</b>	<b>Description</b>
<b>Lens accessories</b>		
526-51513	LO C 8	Lens, C mount, 8 mm
526-51514	LO C 12	Lens, C mount, 12 mm
526-51515	LO C 16	Lens, C mount, 16 mm
527-51129	ETS	Lens, C Mount , spacer ring set
527-51132	LPT 45 CML 5	Lens, C Mount Housing, Over Housing, IP65, flange 5 mm
533-01010	VF T M1	Infrared filter for C-mount lens
<b>Test equipment</b>		
543-11022	ST V10	Testbox VISOR
994-51135	ST M12-12	VISOR power supply with plug M12 12 pole. Euro plug
994-51138	ST M12-12-M	VISOR power supply with plug M12 12 pole. Multi plugs
543-11001	MA 45	Mounting, Camera Bracket
543-11002	MB 45	Mounting, Block rod camera
543-11003	MP 45	Mounting, Plate for camera
543-11004	MZ 45	Mounting, Adapter for rods
543-11005	MST 45-20	Mounting, Rod 20 cm camera
543-11007	MST 45-40	Mounting, Rod 40 cm camera
543-11008	MG 45	Mounting, Hinge camera
543-11013	MA 45 L	Mounting, Camera Bracket long
543-11021	MK 45 L	Mounting, Long Dovetail mounting bracket
<b>Mounting</b>		
543-11023	MG 2A	Mounting, Dovetail mounting bracket, 2 axis rotation
543-11015	MA LR-100/M12	Fixing bracket ring light, diameter 100 mm, for LFR115
<b>External illumination</b>		
525-51150	LFR115 WD-24-2L12	Illumination, VISOR, Ring, LFR115, White, diffuse, 2 x M12/M12 pole
525-51151	LFR115 RD-24-2L12	Illumination, VISOR, Ring, LFR115, Red, diffuse, 2 x M12/M12 pole
525-51152	LFR115 ID-24-2L12	Illumination, VISOR, Ring, LFR115, InfraRed, diffuse, 2 x M12/M12 pole
532-51024	LF 200 WD-24-KFL5	Surface light diffuse, 200 mm, white
532-51025	LF 200 RD-24-KFL5	Surface light diffuse, 200 mm, red
525-01001	LA45V-24-2L12	Illumination, VISOR, Amplifier adapter, 2 x M12/M12 pole
902-51806	CB L12FS / L12FS- 0,5m-GG-PUR	Illumination, VISOR, Cable, 2 x M12/M12 pole, 0.5 m, straight connector, shielded
<b>Reflective foil</b>		
904-51643	RF 775x...mm	Reflective foil, width 775mm, var. length, self-adhesive, (price per 100mm length)

## 9 Useful links and contacts

Free download of Vision Sensor VISOR® PC Software with sample images including <i>SensoFind</i> , <i>SensoCalc</i> , <i>SensoConfig</i> , <i>SensoView</i>	<a href="http://www.sensopart.com/en/download/finish/71-software/1720-visor-pc-software-v1300">http://www.sensopart.com/en/download/finish/71-software/1720-visor-pc-software-v1300</a> Registration required
VISOR® user manual	After installation of above software: Windows START / All programs / SensoPart / VISOR Vision sensor / documentation / user manual
SensoCalc	After installation of above software: Windows START / All programs / SensoPart / SensoCalc
Manual on Ethernet communication	After installation of above software: Windows START / All programs / SensoPart / VISOR Vision sensor / Tools / Ethernet
Product Finder	<a href="http://www.sensopart.com/en/products">www.sensopart.com/en/products</a>
CAD drawings	<a href="http://www.sensopart.com/downloads">www.sensopart.com/downloads</a>
Technical support	<a href="mailto:support@sensopart.de">support@sensopart.de</a> +49 7665 94769-750

## Appendix A: Test sample

