Schäfter + Kirchhoff

Schäfter + Kirchhoff GmbH

CCD Line Scan Camera System

Software program

SkLineScan-GigE-WIN

Manual

Windows 7 (32 / 64 bit)

Version 5.4.0

12/2015

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SkLineScan-GigE-WIN – Manual (Version 5.4.0 Windows 7)

1 Introduction

The operating program SkLineScan visualizes the brightness signal of the connected line scan camera on the PC monitor as an oscilloscope. Using this display the user can adjust the optical system with camera, lens and illumination. The operation parameters of the camera can be changed interactively during the scan acquisition. With zoom and scroll functions each individual pixel of the CCD line signal can be displayed. Furthermore the program demonstrates the two-dimensional area scanning of surfaces with the CCD line scan camera. Saving of images is possible.

The SkLineScan progam is suitable for line scan cameras with GigE Interface, which connected at PCs or Notebooks with operating systems Microsoft Windows 7 (x64, x86).

2 Basics of the CCD Line Scan Camera System

CCD (Charge Coupled Device) line scan cameras are semiconductor cameras with one single photosensitive line, which contains – depending on sensor type – up to 22800 individually addressable picture elements (pixels) from 5 - 25 microns width. Light energy incident on the sensor is transformed into an electric signal; shift registers following the bucket chain principle transport this. The transfer rate is determined by the pixel frequency. For further processing in the PC the signal must be digitized. The analogue/digital conversion is done in the camera itself. At 8-bit-resolution, the A/D converter transmits the output voltage of each pixel into one of 256 brightness levels, at 12 bit resolution into 4096 brightness levels.

The advantages of the CCD line scan camera are

- high optical resolution up to 8160 pixels (monochrome) and 3x7600 (RGB),
- high speed up to 54 kHz line frequency,
- flexible parameter setting of the line scans,
- free synchronizing of each individual line

The image produced by a line scan camera represents the brightness profile of the test object captured by the line sensor. A two-dimensional image is possible, by performing a scanning movement of either the object or the camera, during which the individual line signals are transferred to the computer and assembled to produce a composite 2D image.

Generally, the applications can be grouped into one-dimensional and two-dimensional measuring tasks. For one-dimensional applications the measured result is extracted from the pixel information of an individual line scan. Measurements in two-dimensional images require moving the object or the line sensor.

Camera application:	1-dimensional	2-dimensional
Signal / Image generation:	Individual line scan	Several line scans are combined to a 2D image (frame)
Examples:	Measurement of width, edge positions, glass thickness	Surface inspection, texture analysis, scanner

Table 1: CCD line scan camera applications

For an image to be correct in all proportions, the scanning speed and the image acquisition process must be synchronized and this is most easily achieved by adjusting the transport speed to the line frequency of the camera. However, in practice, it is usually the transport speed and the image resolution that are constraining and these predefine the line frequency.

At constant transport speeds, such as when examining objects on a conveyor belt, a line scan camera can be allowed to operate in a free-running mode. Conversely, any velocity fluctuations or discordant movements require the coordinated triggering of the line camera over equally spaced increments. The most convenient solution is for the software control unit of the transport motor to be made responsible for coordinating the individual line scans also. This precise synchronization guarantees images with a reproducible resolution and correct aspect ratio (see Figure 1). The line frequency f_L can be calculated for a given object speed v_0 and field width FOV, sensor length S and pixel width w from
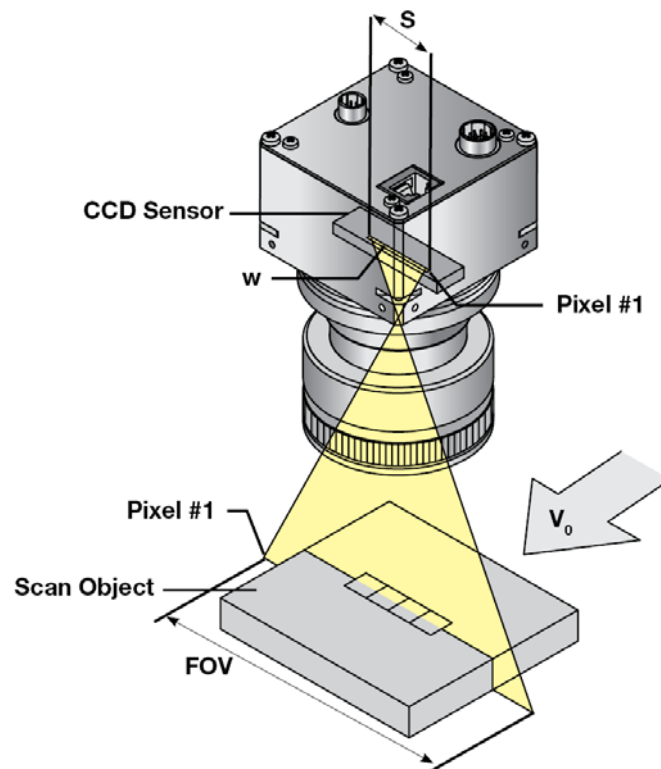
$$f_L = \frac{v_0 \cdot S}{w \cdot FOV}$$

Fig. 1: Relation of travel velocity, field of view and line frequency to acquire an image with correct aspect ratio.

3 Installation

Before the camera will be connected the software should be installed. At first the CD *SK91GigE-WIN* must insert in the CD-Drive. The setup program will be started automatic. If not then start the *SK91GigE-WIN_x64 / x86.msi* manually from the CD. Please follow the dialogs of the setup program to install the SK91GigE-WIN software. The Pleora driver for the line scan cameras will install automatically while the setup process.

Folder structure after installation of 64 bit version:

Folder name	Content
C:\Program Files\SK\SK91GigE-WIN	
\SKLineScan	SKLineScan (executeable)
\Manual	Manuals (also this manual)
C:\Program Files\Common Files\SK	
\SK91GigE-WIN\Bin	64 Bit DLLs (folder registered in system path variable)
C:\Program Files (x86)\Common Files\SK	
\SK91GigE-WIN\Bin	32 Bit DLLs (folder registered in system path variable)
C:\Users*user*\AppData\Roaming\SK\SK91GigE-WIN\Settings	camera settings

Folder structure after installation of 32 bit version:

Folder name	Content
C:\Program Files\SK\SK91GigE-WIN	
\SKLineScan	SKLineScan (executeable)
\Manual	Manuals (also this manual)
C:\Program Files\Common Files\SK	
\SK91GigE-WIN\Bin	32 Bit DLLs (folder registered in system path variable)
C:\Users*user*\AppData\Roaming\SK\SK91GigE-WIN\Settings	camera settings

The \Bin folders are registered in the path environment variable of the system, so that all application programs can access the SK91GigE_x64.dll and SK91GigE_x86.dll.

Note: In the folder names is '*user*' a placeholder for your windows username.

4 GigE Interface and System Requirements

GigE cameras use the 1000 Mbps bandwidth of Gigabit Ethernet for a fast and secure transfer of video and control data between camera and PC. Standard CAT5e and CAT6 Ethernet cables can be used to transfer data over distances of up to 100 m. Data is acquired directly by the PC or laptop with standard network components. An additional grabber board is not required.

The speed of the camera data transfer via Gigabit Ethernet is possible up to 80 MByte/s with a CPU load of only 1%.

To reach the maximal performance of the GigE camera system the using of a network interface card (**NIC**) with **Intel PRO/1000 chip** and the High Performance Driver of the SK91GigE software package is recommended.

NICs, which do not work with the High Performance Driver must have a fix IP address (e.g. 192.168.0.99).
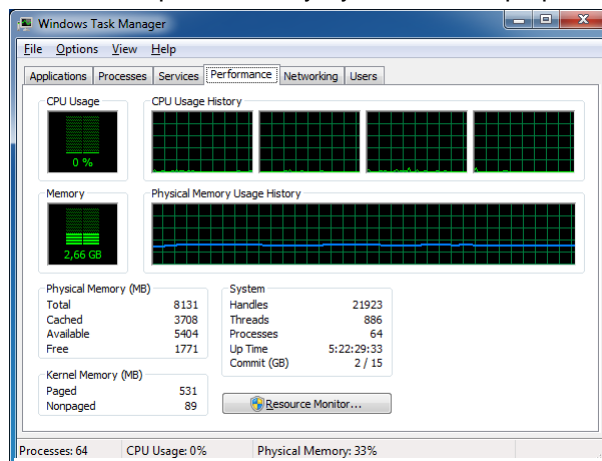
Fig. 2: CPU load measured during GigE data transfers

If two or more cameras work parallel they can be plugged at a GigE switch, which is connected with the NIC, or every camera is plugged at their own GigE NIC in the PC. In the 1st case all cameras must share the GigE bandwidth. In the 2nd case for every camera the full bandwidth is available. A mix of GigE switches and GigE NICs is possible. But all GigE NICs must run in the same mode – with High Performance Driver or with standard network driver. In the properties of a standard network driver for a GigE adapter *Jumbo frames* must be enabled.

The High Performance Driver does not need any additional settings. The NIC becomes to a grabber.

The Firewall needs to be turned off !

System Requirements
• Intel Pentium 4 or AMD equivalent
• RAM min. 1 GByte, depending on size of acquired images
• High-performance video card using either an AGP bus or PCI Express bus
• Operating System: Windows XP, Windows Vista, Windows 7 (32-bit and 64-bit) are supported

Network Interface Cards
• Any Gigabit Ethernet network interface card (NIC) as a card or on the motherboard is suitable. For the best performance, a NIC with Intel PRO/1000 chip is recommended.
• PCI Express adapters will outperform PCI adapters.
• Network interface cards that support Jumbo Frames will outperform adapters with fixed packet-size frames.

4.1 Optimizing the Network Interface Card

This described optimizations are not necessary for the High Performance Driver of Pleora.

Most Gigabit network interface controllers allow user modifications of parameters, such as adapter buffers and jumbo frames. These should be optimized during the installation in the advanced properties of the network adapter.

To configure the advanced properties of the network adapter, following steps must be done:
- Click on **windows start button** – **Control Panel**
- Open **Network and Sharing Center**
- Click on **Change adapter settings**
- Right click on **appropriate network adapter** – select **Properties**
- Click on **Configure** – select tab **Advanced**
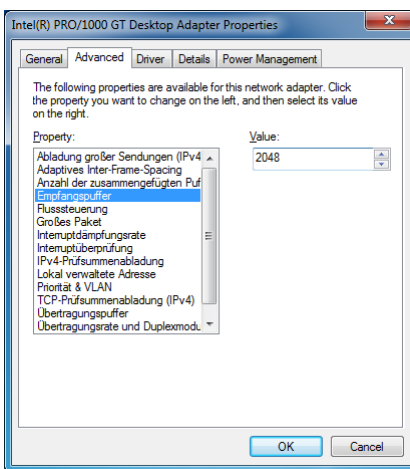
Fig. 3: Adjust receive buffer (Empfangspuffer)
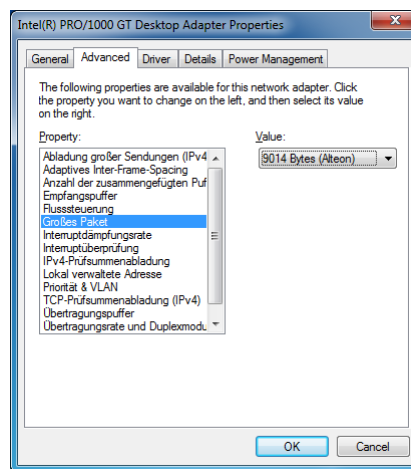
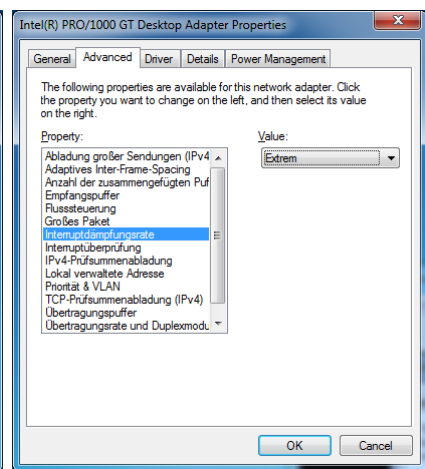Fig. 4: Select jumbo frame (Großes Paket)

Fig. 5: Set interrupt rate of damping (Interruptdämpfungsrate) to 'Extrem'

Next step is to set the ip address of the network adapter to a static address:
- Click on **windows start button** – **Control Panel**
- Open **Network and Sharing Center**
- Click on **Change adapter settings**
- Right click on **appropriate network adapter** – select **Properties**
- Double click on **Internet Protocol Version 4 (TCP/IPv4)**
- Select the radio button **Use the following IP address:**
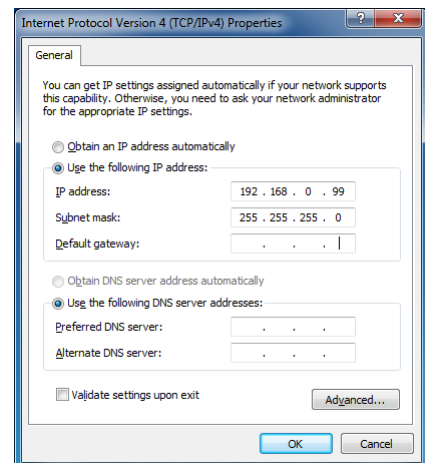- IP address: 192.168.0.99 / Subnet mask: 255.255.255.0 (for example)

Fig. 6: Set ip address to static one

5 Operating SKLineScan Program

5.1 Start-up and Setup Dialog

After the program has been started a start-up window appears, which displays the connected cameras. The camera type will be detected automatically. It is important that the displayed camera type is identical with the connected line scan camera. If not, close the program, disconnect the camera, wait few seconds before reconnect the camera and start the program again.

Acknowledge the start-up dialog by *OK*. After closing the start-up dialog a window with the oscilloscopic view of the line scan signal appears.
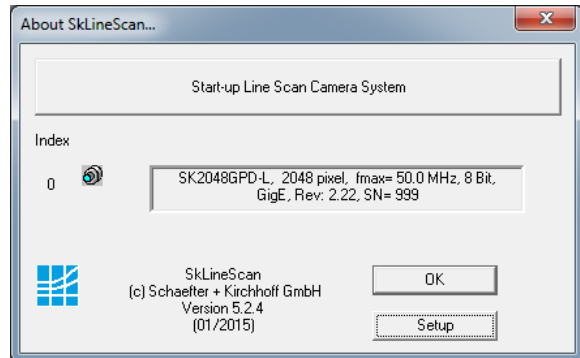
Fig. 7: Start-up window in SKLineScan program

With the click at the *Setup* button a new dialog will be opened. All connected cameras are sorted by their Camera ID. It is possible to deactivate or activate several cameras by click at the checker control field. Please note, the greater the number of activated cameras the higher CPU uses is needed. Furthermore the pixel frequency and the bit depth can be changed.
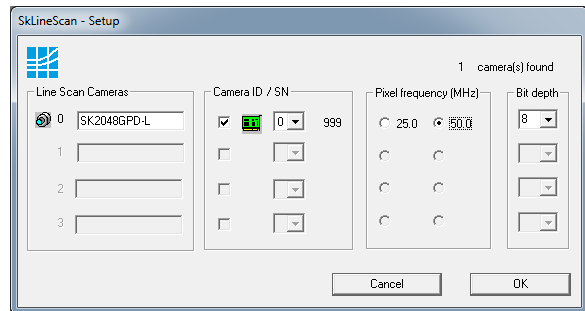

Fig. 8: Setup dialog in SKLineScan program

5.1.1 Multi Camera Operation

The SKLineScan program supports multi camera operation with up to 4 cameras. Each camera get an index number (Camera ID) to identify the camera. The IDs start by 0. The order of the assignment of the IDs is given by the USB controller port assignment. The camera which is connected to USB port 0, gets the Camera ID 0, a.s.o.

Acknowledge the start-up dialog by *OK*. After closing the start-up dialog a window with the oscilloscopic view of the line scan signal appears for each detected camera. In the window title stands the camera name, the ID and the serial number for identification of the cameras.
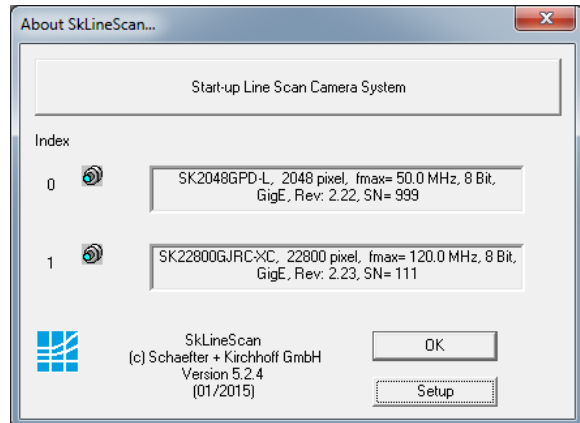
Fig. 9: Start-up window in SKLineScan program with multi camera operation

If the given order is not as desired then a manual customization of this order is possible. For this customization click on *Setup* to open the setup dialog for the cameras.

In the opened dialog is the ability to change the Camera ID under the point *Camera ID / SN*. The new ID of the camera can be selected in the drop down menu in the middle of the section. After the click on the new id the parameters (name, pixel frequency, etc.) will change immediately. This is shown in the figures 7 and 8. Here switched the SK22800GJRC-XC with the SK2048GPD-L.
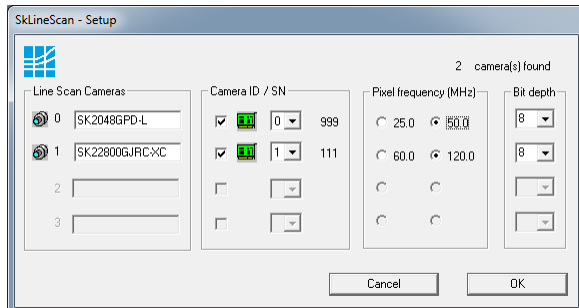

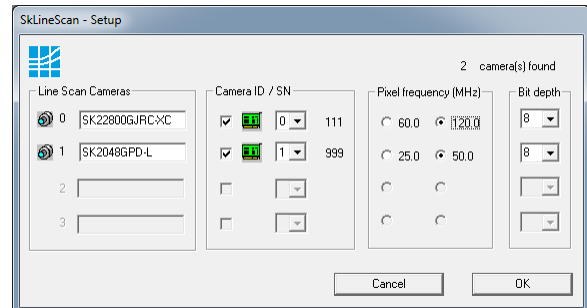*Fig. 11: Before switching the Camera ID*

Fig. 10: After switching the Camera ID

Other options of the setup dialog are the change of the pixel frequency or the bit depth. It is possible to activate or deactivate the cameras with the check box under the section *Camera ID / SN*. The third row in the section *Camera ID / SN* stands for the serial number (SN) of the camera.

5.2 Function Overview
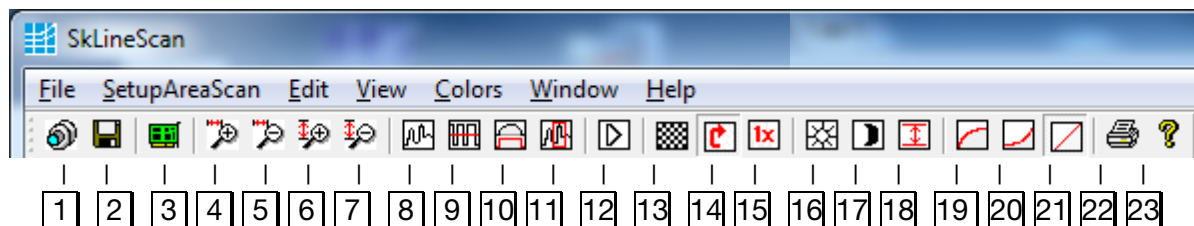
1:      New line scan. All open signal windows will be closed. ([F2])

2:      Save brightness profile of a single line scan, or the image of a 2d scan

3:      Open / Close the camera control dialog. ([F4])

4:      Zoom IN, x-axis.

5:      Zoom OUT, x-axis

6:      Zoom IN, y-axis.

7:      Zoom OUT, y-axis

8:      New line scan. Keeps open line scan windows. Area scan window will be closed. ([F2])

9:      Activates the Threshold mode (only for monochrome line scan cameras).

10:      Opens the dialog for Shading-Correction and Lookup table programming. ([Alt] + [S])

11:      Opens the dialog for Window Function (ROI settings). ([Alt] + [W])

12:      Dialog for Gain / Offset control, and input serial commands. ([Shift] + [F4])

13:      Starts an area scan. ([F3])
use *SetupAreaScan* for input the number of lines per image before start an area scan.

14:      Repeatedly grabbing.

15:      Snap an image.

16:      Multiply the pixel intensity times 2 for more brightness of an area scan (b is displayed in status bar)

17:      Reduce the pixel intensity for lower brightness of area scan (/ 2).

18:      Contrast enhancement using histogram (only in area scan mode).

19:      Lookup table programming with Gamma function (g > 1.0).

20:      Lookup table programming with Gamma function (g < 1.0).

21:      Linear lookup table.

18:      Print.

18:      About dialog.

5.3 Oscilloscope Display of Line Scan Signal

The sensor of a line scan camera is one-dimensional and, therefore, the image produced is made up of a single line and represents the brightness profile of the equivalent object line directly mapped onto the sensor line.
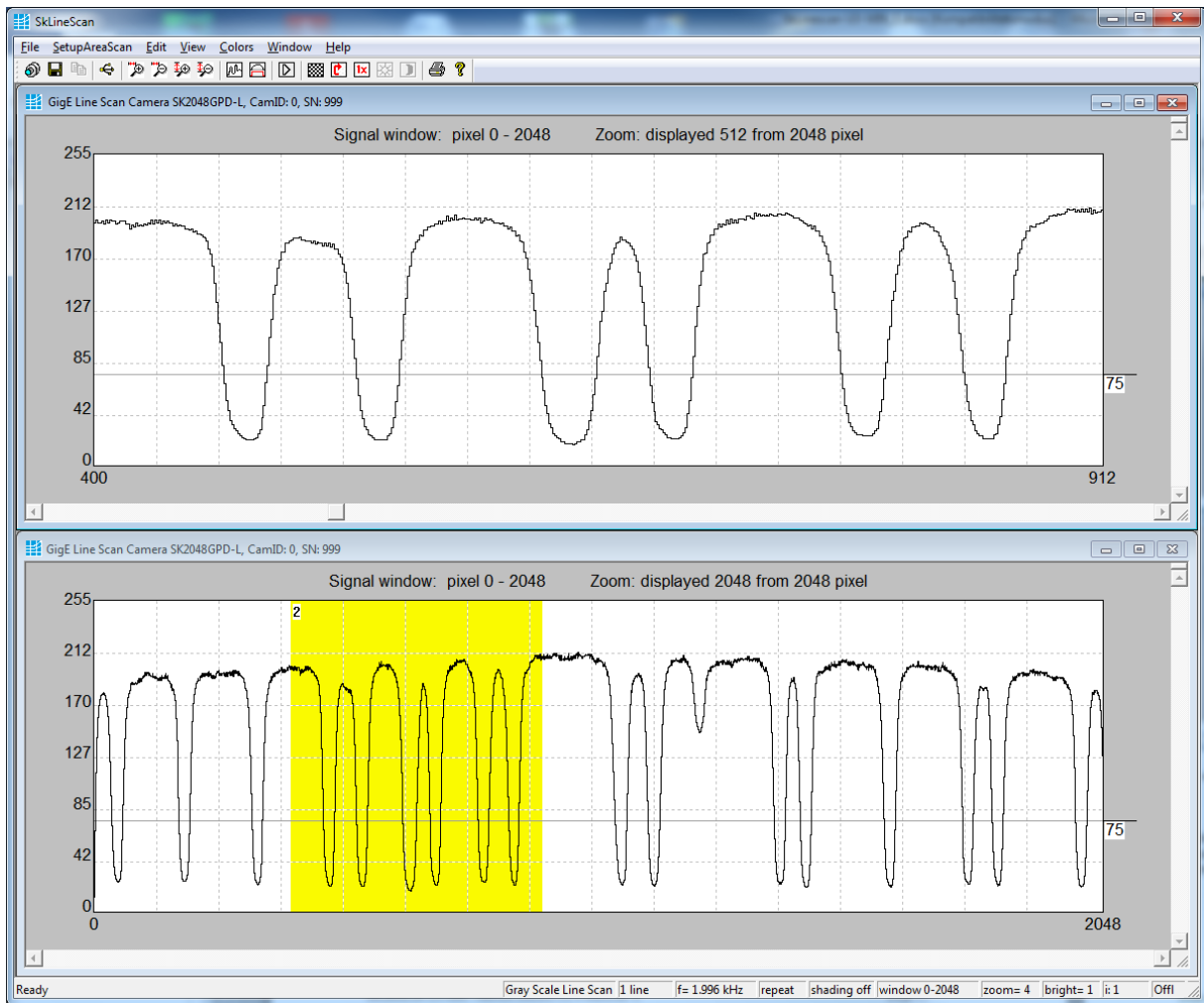
The oscilloscope display plots the digitalized brightness profile as signal intensity (y-axis) against sensor length (x-axis) at a high refresh rate. The scaling of the y-axis depends on the resolution of the A/D converter: at 8-bits the scale is from 0 to 255 and at 12-bits from 0 to 4095. The scaling of the x-axis corresponds to the number of pixels in the line sensor.

Especially with large sensor lengths, the full details of the signal are only visible after using the zoom function. Zooming of one or several sections of the signal allows visualize every individual pixel.
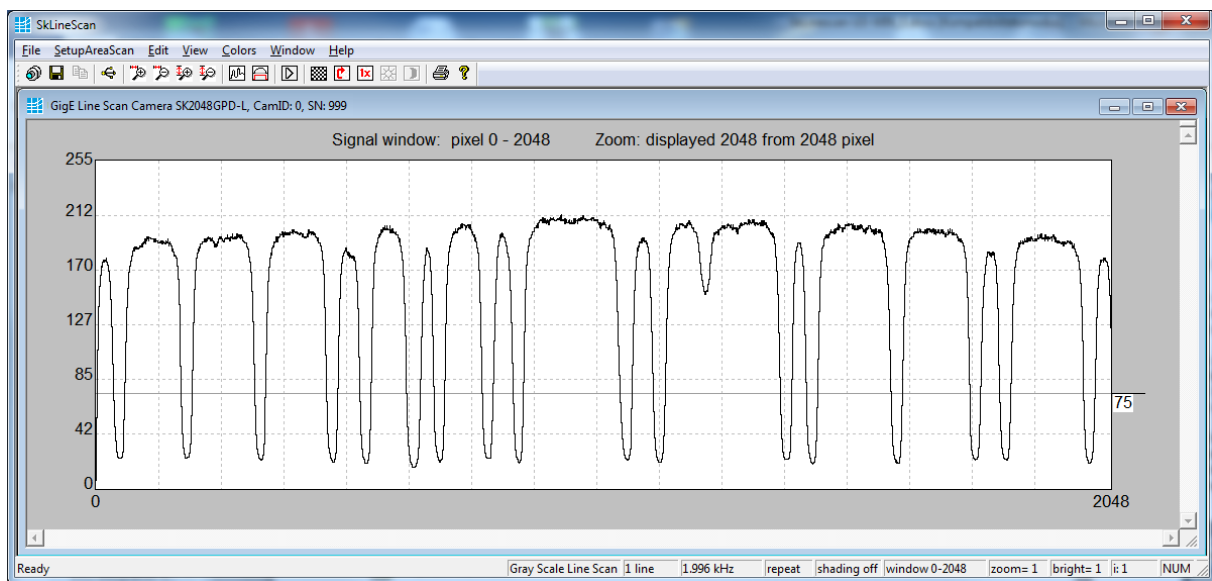

5.3.1 Zoomed View X-Axis

- For a zoomed display, it is preferable to open another or more windows by ![icon], or **[F2]** and then split the window.

- To split the window, place the mouse pointer on the split facility at the top of the scroll bar, hold down the left mouse button and pull the mouse pointer down to the middle of the screen.

- Click on one of the windows and adjust the zoom factor and zoom range on x-axis using ![icon] or ![icon].

- Close the zoom function window, either reverse the split procedure or close both split windows by clicking on the X sign and open a new line scan window with **[F2]** or by clicking on the camera icon.

Optimal signals are only obtained when the lens is correctly focussed and a form of white balance or shading correction has been performed. Shading Correction compensates for non-uniform illumination, lens vignetting as well as any differences in pixel sensitivity.

5.3.2 Zoomed View Y-Axis

- For a zoomed display, it is preferable to open another or more windows by ⌷ , or **[F2]** and then split the window.

- To split the window, place the mouse pointer on the split facility at the top of the scroll bar, hold down the left mouse button and pull the mouse pointer down to the middle of the screen.

- Click on one of the windows and adjust the zoom factor and zoom range on y-axis using ⌷ or ⌷.
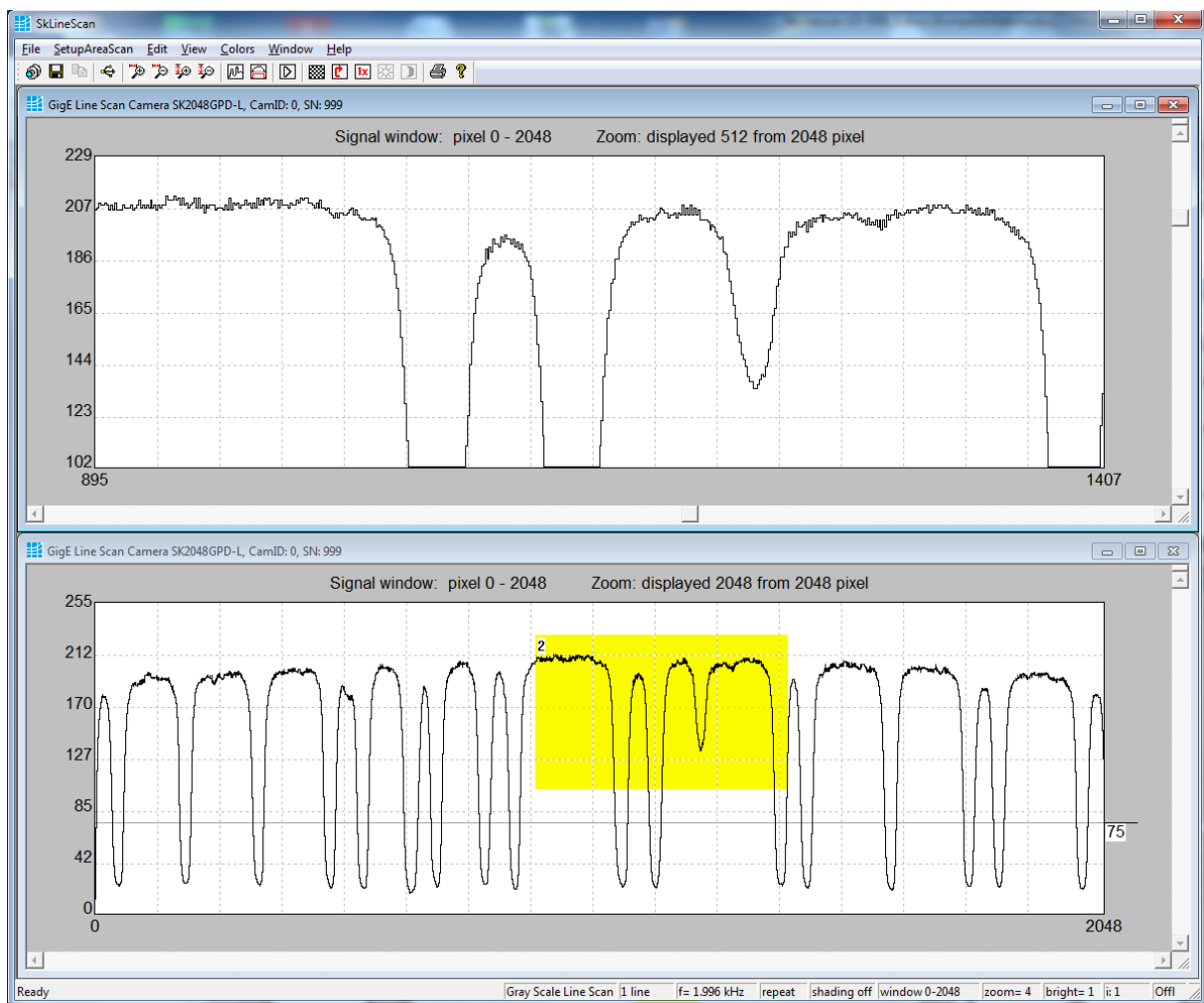
- Close the zoom function window, either reverse the split procedure or close both split windows by clicking on the *X* sign and open a new line scan window with **[F2]** or by clicking on the camera icon.

Optimal signals are only obtained when the lens is correctly focussed and a form of white balance or shading correction has been performed. Shading Correction compensates for non-uniform illumination, lens vignetting as well as any differences in pixel sensitivity.

5.3.3 Save Line Scan Signal

It is possible to save the line scan signal as a image in png or bitmap format or to save it as raw data. Raw data means a txt or csv file where for each pixel the intensity is stored.
It is recommanded to save the image as png. Png is a lossless compression format.

Fig. 12: Save line scan signal as image or raw data

To save the data as raw data, use the following:
Hot Key: **[Ctrl] + [S]**
Menu: **File** – **Save CSV**

To save the data as image:
Hot Key: **[Ctrl] + [Alt] + [S]**
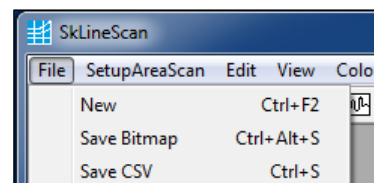Menu: **File** – **Save Bitmap**
Toolbar Icon: 🖫

5.4 Lens Focussing

The oscilloscope display facilitates the effective focussing of the line scan camera system, even for two-dimensional measurement tasks. For determining the correct focus, the edge steepness at dark-bright transitions and the modulation of the line scan signal are the most important factors.

- Adjust the focus using a fully opened aperture to restrict the depth of field and to amplify the effects of focus adjustments.

- The signal amplitude may have to be trimmed when using a fully opened aperture and this can achieved most readily by shortening the integration time.
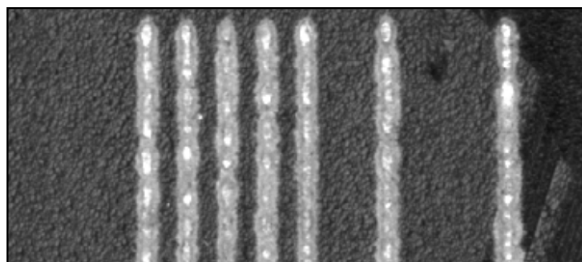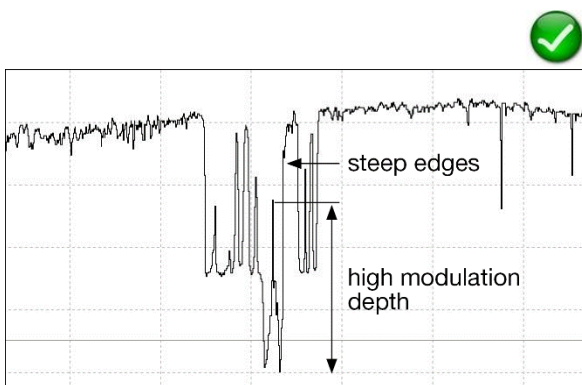
Line scan camera signal - ideal focus settings

- Dark-bright transitions with steep edges
- Large modulation in the signal peaks
- High-frequency gray value variations
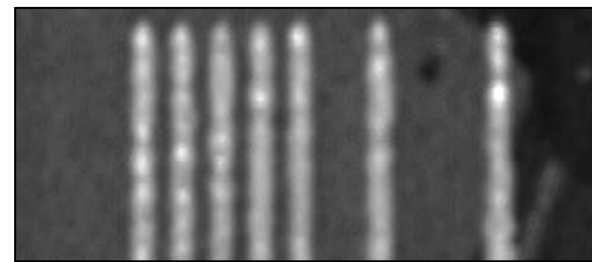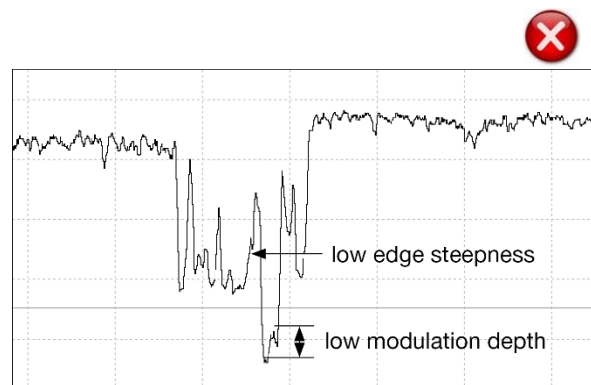
Out-of-focus line scan camera signal

- Low edge steepness
- Signal peaks are blurred
- High-frequency gray values with low modulation

5.5 Camera Control

To open the camera control dialog, use the following:
Hot key: **[F4]**
Menu: **Edit - Operation Parameters**
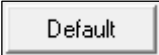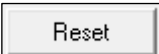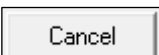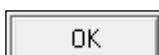Toolbar Icon: ▦

Integration Time:
Moving the right vertical slider makes fine adjustments to the integration time. The left slider affects the time range of the right slider to control the integration time. The larger the time range is the coarser the regulation, and the smaller the time range is the more precise the integration control.
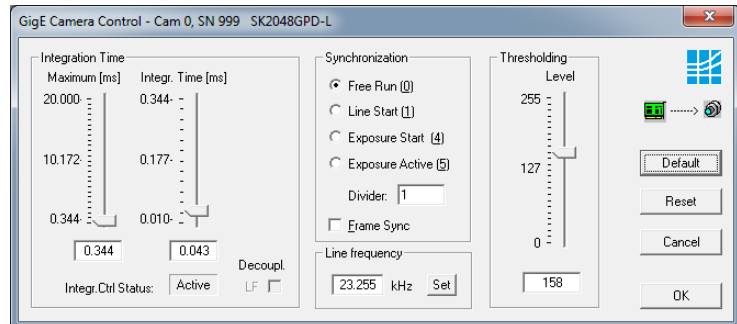
Use the **Default** button for reset all sliders. The integration time is adjusted as the reciprocal of the maximum line rate. The current line frequency is displayed in the Line Frequency status field.

E.g., the default integration time of a SK2048GPD-L camera is 43 µs, what is equivalent to 23.255 kHz line frequency.

The adjustment of the integration time in the range of Integration Control (shutter) with an integration time shorter than the minimum of exposure period does not change the line frequency. It will be held at maximum.

Default	Sets the integration time to the limit of exposure period (maximum line frequency).
Reset	Reprogramming of integration time to the start value.
Cancel	Closes the camera control dialog and resets integration time to the start value.
OK	Uses the programmed parameters and closes the camera control dialog.

Synchronization

The functioning of synchronization modes is described in section 5.5.3.
Note: For LineSync and FrameSync, there are separate signal inputs at the camera I/O connector. (s. camera manual)

In external synchronization modes **Line Start** and **Exposure Start**, it is possible to divide the input clock by an integral factor.
Valid values of Divider are:

0 = divide by 1 -> line frequency is equal to the frequency of external TTL signal
1 = divide by 2 -> line frequency is half of the external TTL signal frequency
2 = divide by 3 -> line frequency is one third of the external TTL signal frequency
Maximum divider value: 2^{32-1}

5.5.1 Integration Time and Exposure Period

The light sensitive elements of the photoelectric sensor accumulate the charge that is generated by the incident light. The duration of this charge accumulation is called the **integration time**. Longer integration times increase the intensity of the line scan signal, assuming constant illumination conditions.

The complete read-out of accumulated charges and output procedure determines the **minimum exposure period**, which is a function of sensor length and the minimum number of clock cycles required to complete the read-out and output process. Thus, the minimum exposure period of particular line scan camera determines the **maximum line frequency** of that camera and this is declared in the data sheet of the particular camera type.

For example, the SK2048GPD-L line scan camera with 50 MHz pixel frequency:

maximum line frequency	f_{Lmax}	= 23.255 kHz
minimum exposure period	t_{Emin}	= 0.043 ms

5.5.2 Integration Control

Integration Control allows the **integration time** of light-induced charge accumulation to be set at a value that is shorter than the **minimal exposure period** for the designated CCD line scan camera. Integration Control works like a shutter by stopping pixel charge accumulation, thereby restricting the integration of the signal. A shorter integration time t_A cannot influence the minimum exposure period and, so, the line frequency remains unaltered.

Examples:

the **SkSetIntegrationTime** parameter is used to program the SK2048U3PD camera with different integration times:

1. 0.043 [ms] → **SK_SETINTEGRATIONTIME(CamID, 0.043):**
   integration time =   0.043 ms; exposure period = 0.043 ms;
                          line frequency = 23.255 kHz (= limit)

2. 0.106 [ms] → **SK_SETINTEGRATIONTIME(CamID, 0.106):**
   integration time =   0.106 ms; exposure period = 0.106 ms;
                          line frequency = 9.434 kHz

3. 0.021 [ms] → **SK_SETINTEGRATIONTIME(CamID, 0.021):**
   integration time =   0.021 ms; exposure period = 0.036 ms;
                          line frequency = 23.255 kHz (= limit)

In example 3, the set integration time is shorter than the minimum exposure period and the camera performs in integration control mode (shutter) automatically. The shorter integration time means that the signal intensity is reduced, but the line frequency remains at the maximum of 23.255 kHz.

5.5.3 Synchronization Modes

Synchronization mode determines the timing of the line scan. Synchronization can be performed internally or by trigger signals sourced externally.
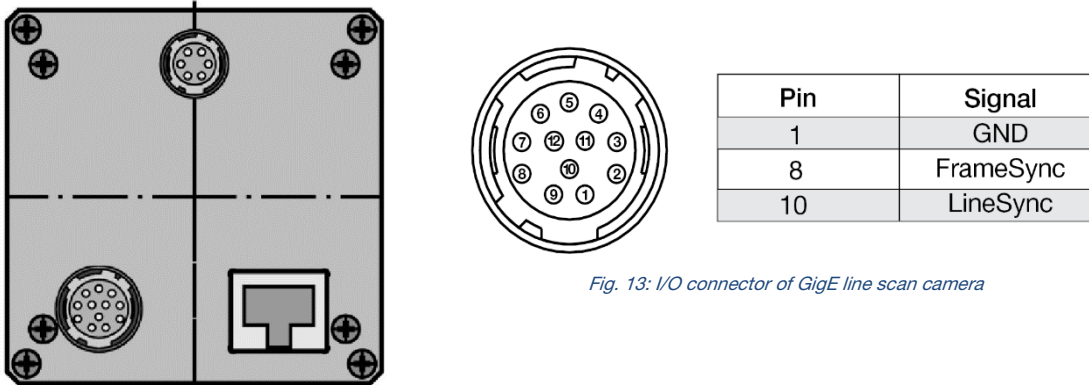

Pin	Signal
1	GND
8	FrameSync
10	LineSync

Fig. 13: I/O connector of GigE line scan camera

The line scan camera system has two modes of external synchronization.

1. **Line**-triggered synchronization
   Each single line scan is triggered by an external signal (TTL).

2. **Frame**-triggered synchronization
   A set of lines for producing 2-dimensional images is triggered (TTL).

The synchronization modes work as follows:

FreeRun / SK Mode 0:
Each line is acquired by internal synchronization of line scans. The completion of one line scan initiates the subsequent line scan immediately (free-running).

LineStart / SK Mode 1:
An external trigger (TTL at Pin 5, falling edge) initiates the read-out of the current exposed line at the next trigger without any effect on the exposure process. The start of exposure is not controlled and the exposure time is determined by the programmed value. The exposed line is held in the camera up until the next trigger. The trigger clock determines the line frequency.
 Restriction: the TTL period must be longer than the exposure time.

ExposureStart / SK Mode 4:
An external trigger (TTL at Pin 5, falling edge) resets the current exposure and starts a new exposure process. The exposure time is determined by the programmed value. The exposed line will be read out with the next trigger. The trigger clock determines the line frequency.
 Restriction: the TTL period must be longer than the exposure time.

ExposureActive / SK extSOS (mode 5):
The start-of-scan (SOS) pulse of the camera is generated externally by a TTL-source. The TTL clock period determines the exposure time of the camera. The exposed line will be read out with the next trigger.

FrameTrigger / SK FrameSync:
Triggering of a set of line scans (frame). The camera waits for a falling TTL edge at the "FrameSync" input (Pin 3). The FrameSync works independently of the programmed line synchronization. The falling TTL edge starts an acquisition of one frame for the programmed number of lines. For further external line synchronization inside of an initiated frame then an additional TTL clock is required for every line event interruption.
 NB: LineSync and FrameSync are separate signal inputs at the camera I/O connector.

5.5.4 Decoupling Line Frequency

This feature allows the decoupling of the line frequency and the integration time. In normally the changing of integration time causes a changing of line frequency. If the feature is activated, the camera holds the current line frequency. The integration time can be controlled in the range from the reciprocal value of the fixed line frequency down to the shortest possible integration time.

This function is useful e.g. in untriggered image acquisition in Free Run mode, if the line frequency is synchronized with the scan velocity and must be constant, but the integration time has to be reduced because of too much light.

Step 1:
Adjust the line frequency to the desired value.
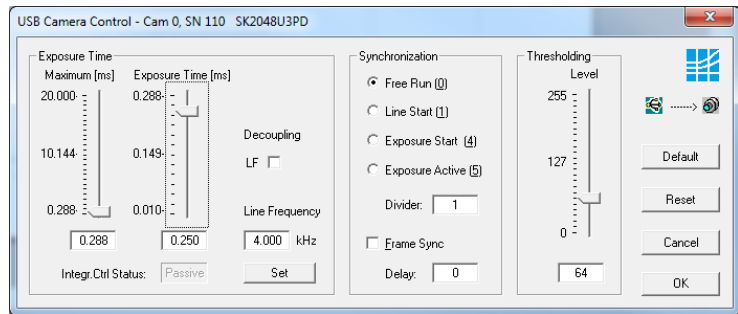
Fig. 14: Select the line frequency which should be hold

Step 2:
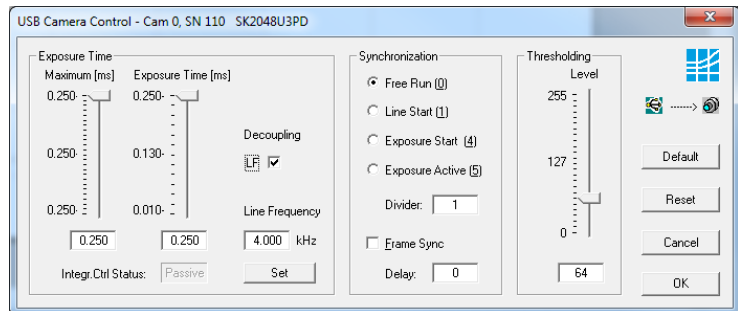Activate the feature with a click on *Decoupl. LF*

Fig. 15: Click on 'Decoupl. LF'

Step 3:
Using the right Slider the adjustment of integration time without changing of line frequency is possible.
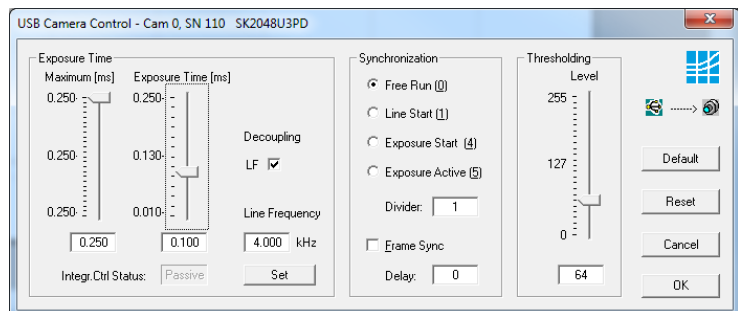

Fig. 16: Change of integration time has no effect to line frequency

5.6 Gain/Offset Adjustments, Serial Commands

To open the gain/offset control dialog, use the following:
Hot key: [Shift+**F4**]
Menu: Edit – Gain/Offset Control
Toolbar Icon: ▷

The line scan camera is provided with correctly adjusted gain / offset. Only if it's necessary, and for camera with, these settings should be changed. This must be done carefully.
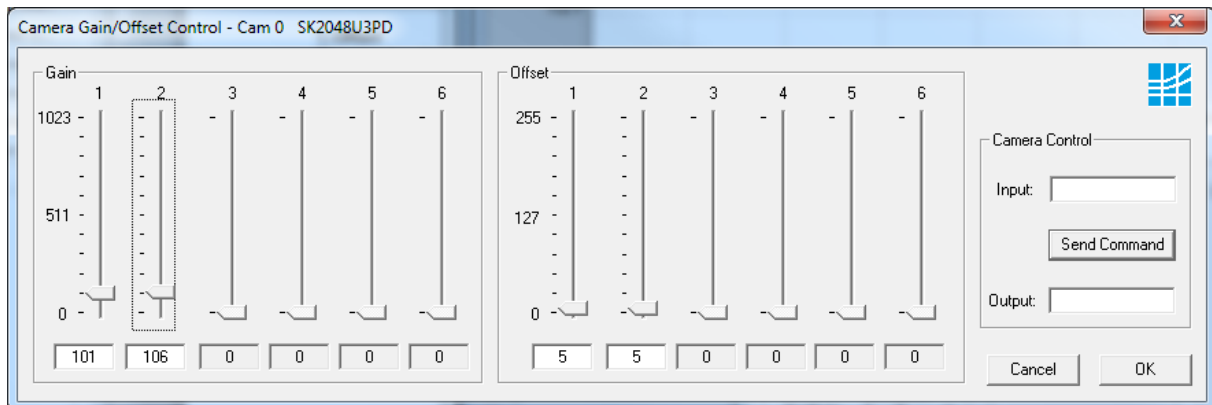
The number of activated sliders for gain and offset corresponds with the number of ADC channels of the camera. Changes to gain and offset settings are immediately visible in the oscilloscope display of the line scan signal.

For monochrome cameras with more than one ADC channel, and for color line scan cameras with more than one ADC channel per color the intensities have to be balanced.

Adjustment principle:

1. Offset
The zero baselines of the video signal must be adjusted. To do this, totally block the incident light. A slight noise should be visible in the zero baseline. If necessary minimize any differences using the Offset sliders.
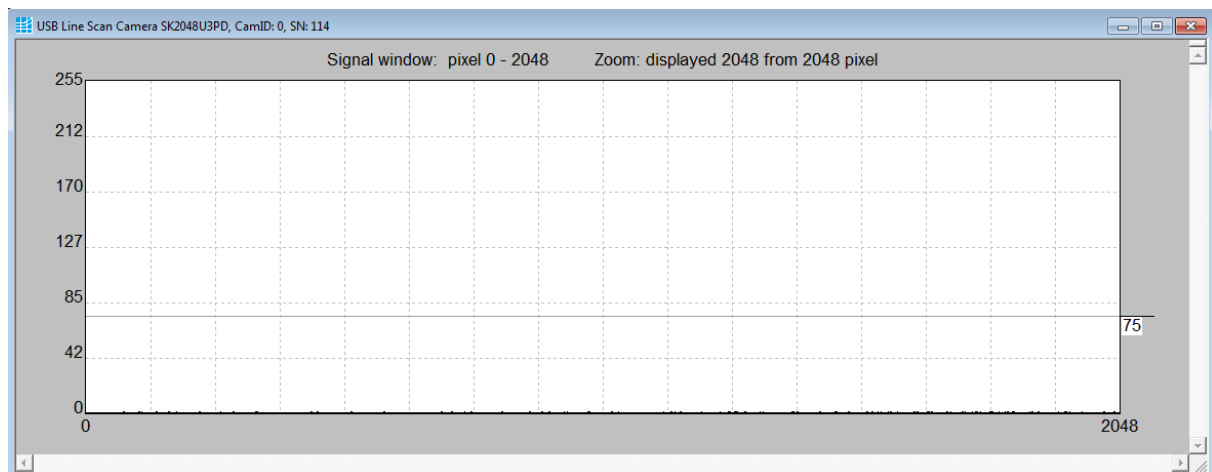

Fig. 17: Line Signal at absolute darkness for offset adjustments

2. Gain
Illuminate the sensor with a slight overexposure to identify the maximum clipping. Use the gain slider "1" to adjust the maximum output voltage. If the camera has two or more channels adjust the signal intensity with e.g. slider "2" to minimize the difference between channels 1 and 2.
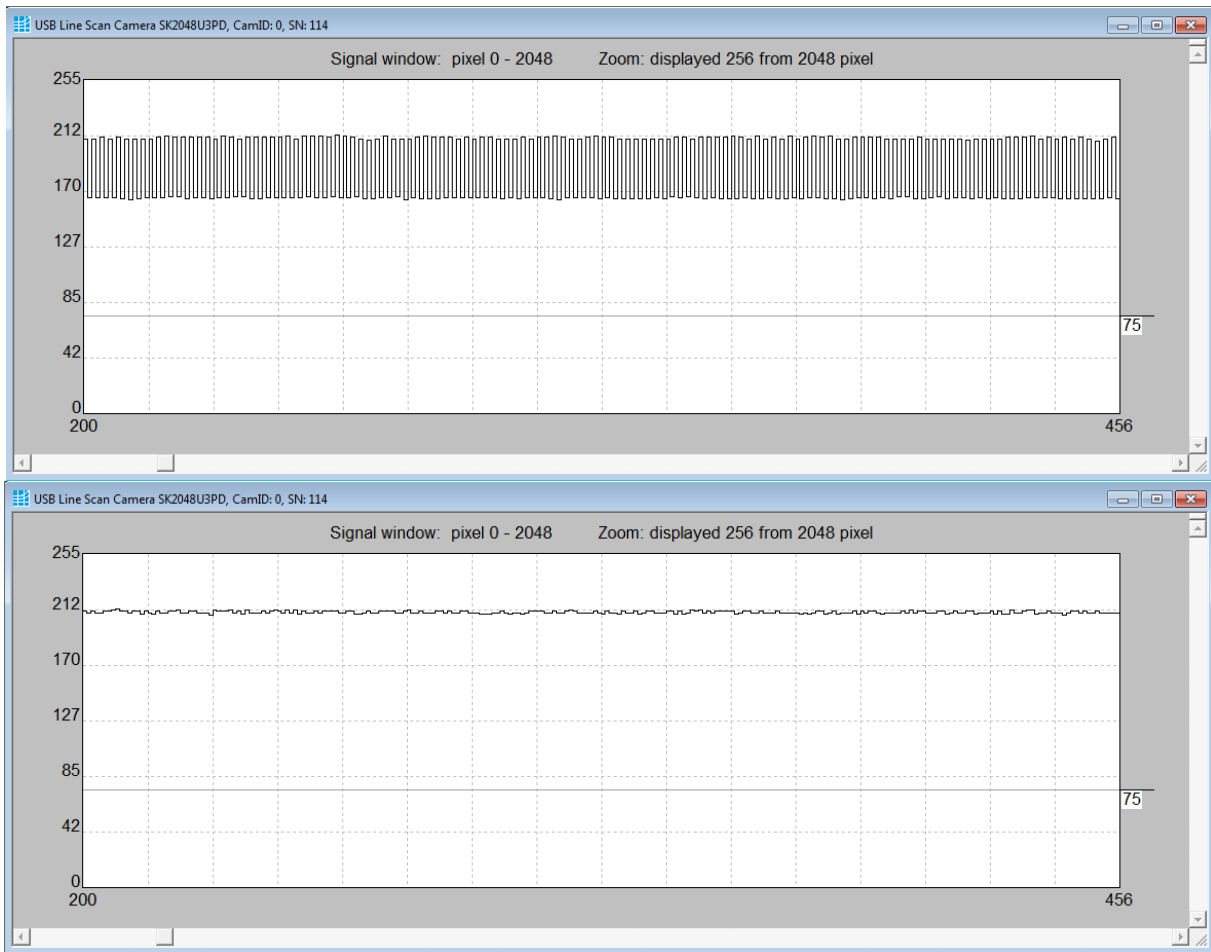
Fig. 18: a) Signal ROI from pixel 200 – 456 with not aligned 1/2 channel,
b) with correct adjusted 1/2 channel

The input field in the Gain/Offset dialog allows the user to send serial commands to the camera and readout the results. The list of serial commands is documented in the manual of the camera.
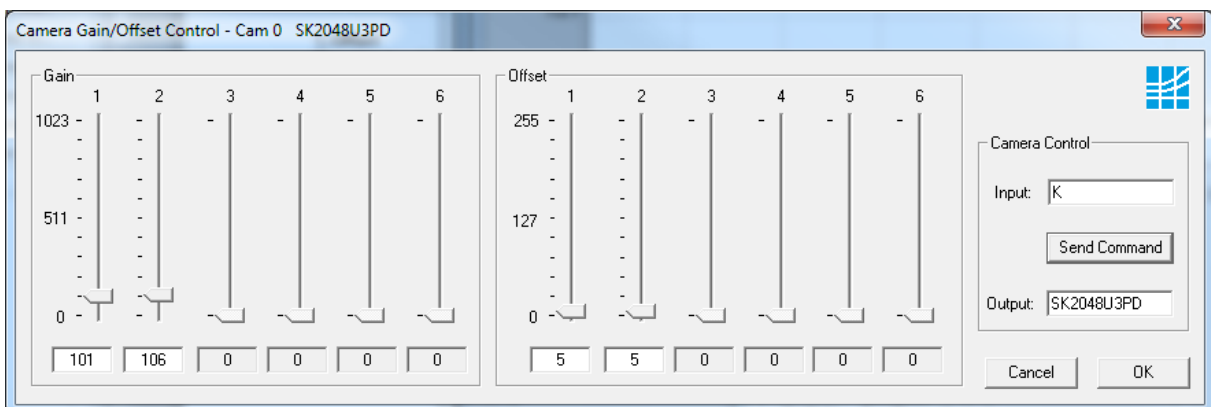

Fig. 19: Gain-Offset-Dialog

5.7 Shading Correction and Lookup-Table Programming

Shading Correction compensates for non-uniform illumination, lens vignetting as well as any differences in pixel sensitivity. The signal from a white homogeneous background is obtained and used as a reference to correct each pixel of the sensor with an individual factor to provide a flat signal, scaled up to programmable intensity. The reference signal is stored in the SCM (Shading Correction Memory) of the camera and subsequent scans are normalized using the scale factors from this white reference.
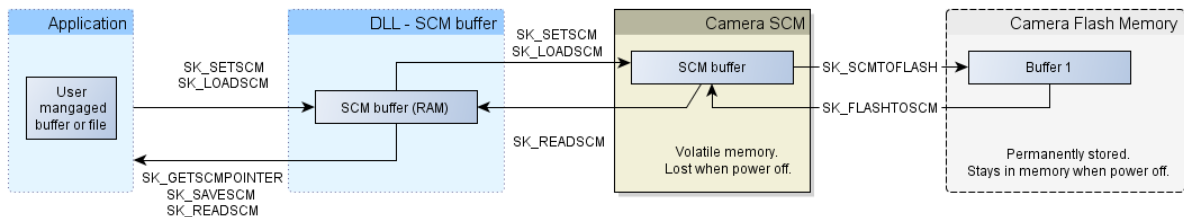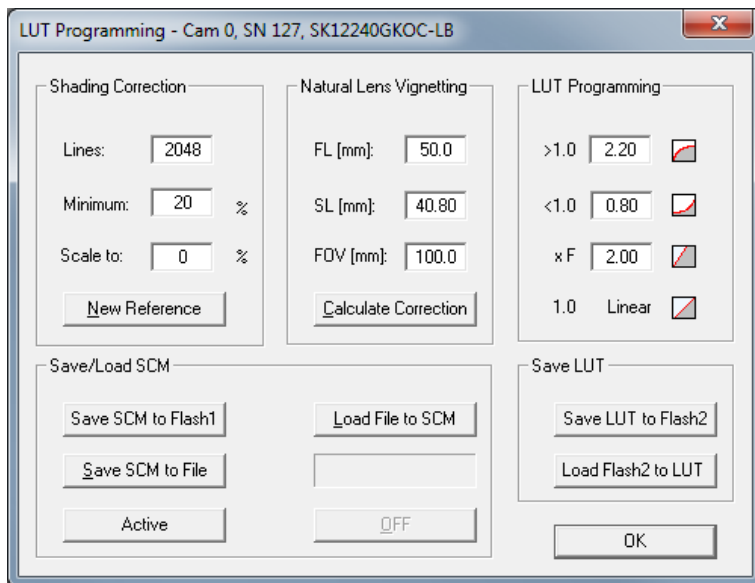

Fig. 20: Structure of Shading Correction Memories

To open the Shading Correction dialog, use the following:
Hot key: **[Ctrl] + [Alt] + [S]**
Menu: **Edit – Shading Correction**
Toolbar Icon:

The line scan cameras have two programmable lookup tables (LUT) inside. The first LUT scales the intensity profile across the sensor. This is used e.g. for Shading Correction, to get a flat intensity profile from a given reference.

The operations of the second LUT affect the intensity values of pixels before digitization. It is useful for correction of brightness, contrast, and dynamic in the image, e.g. by programming the Gamma function. The selected Lookup Table is calculated by using the associated input parameter, and is written in the LUT memory of the camera. The correction operations are done inside the camera, so they don't burden the CPU.

Gamma function g> 1.0:   Boosts the lower intensities non-linear. Dark objects are more visible.

Gamma function g< 1.0:   More contrast by non-linear boosting the higher intensities.

Linear LUT with factor: More brightness by a steeper correction curve, but lower dynamic.

Linear LUT: Original unchanged image.

Save LUT to Flash2 stores the LUT permanently in the camera.
Load Flash2 to LUT reads the stored LUT from Flash2 into the LUT memory and activates it.

Shading Correction

- Use a homogeneous white object for acquisition of the reference. The reference can be a grabbed 2-dimesional area scan about a determined number of lines (call this function from an Area Scan - recommended), or a line signal which was averaged over a number of single line scans. During the image acquisition the white object should be moved to suppress influences of surface structures

- Input the scale range:
    - Minimum in %: intensities lower than "Minimum" will be not changed.
    - Maximum in %: target for scaling. With '0' the result is a flat signal at the maximum of the reference signal (recommended)

- Click on button *New Reference*

- Click on *Save SCM* to **Flash** to save the SCM reference signal in the flash memory of the camera

The camera maintains the data in the flash memory during power-down. If the Shading Correction was active at program exit, it will be re-activated automatically at the next start. The reference signal is restored from the flash memory into the SCM.
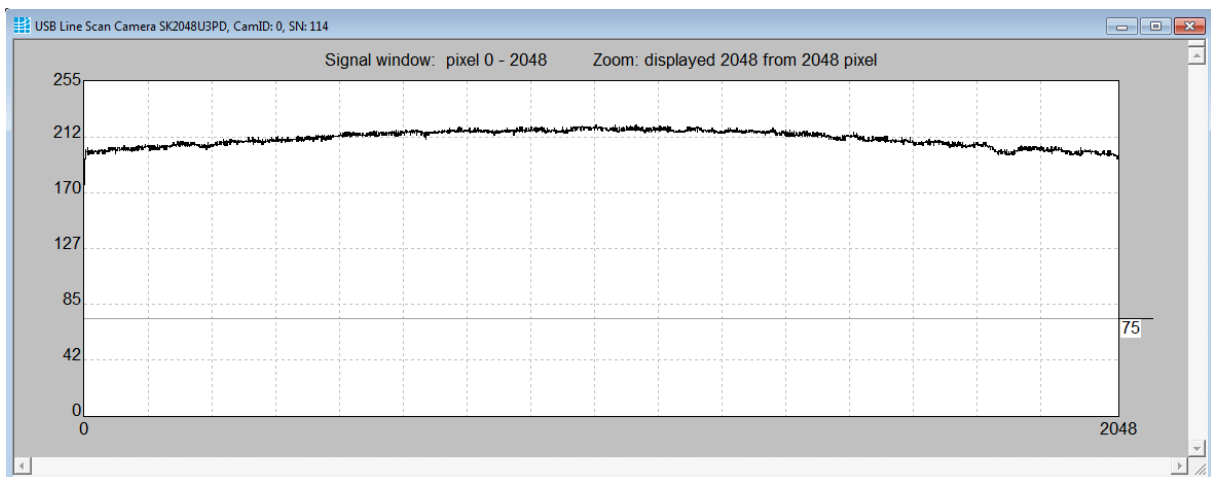

Fig. 21: Line Signal of a white paper sheet before correction

After shading correction, the line scan signal has a homogeneous intensity at the maximum intensity of the reference signal:
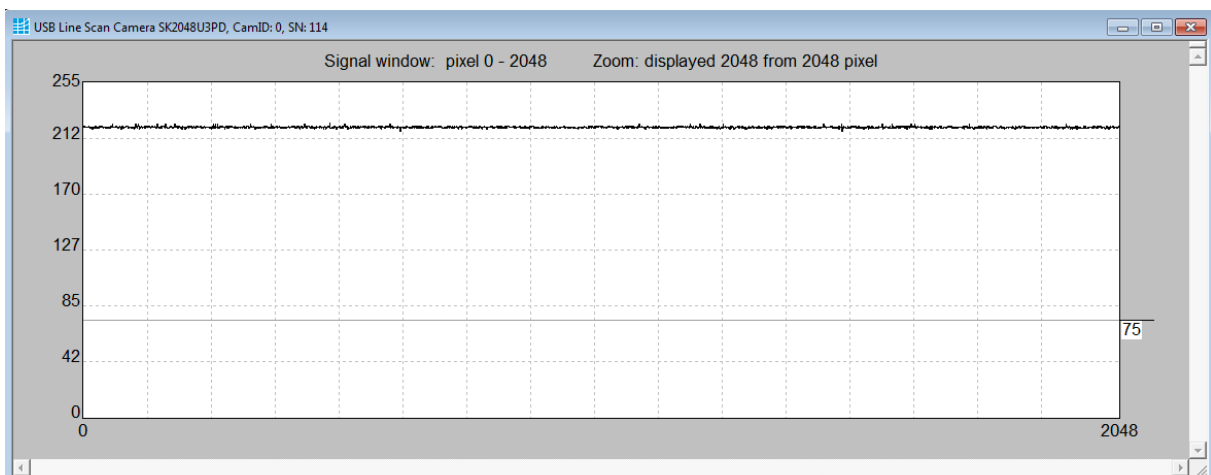

Fig. 22: Line Signal of a white paper sheet after Shading Correction

Fig. 23: Signal of the object in Fig. 9   after Shading Correction

***Active*:**
Activate Shading Correction with the reference signal which is stored in the SCM.

***OFF*:**
Shading Correction turned off. Note: If desired that at the next camera start the Shading Correction is active, save the SCM into the flash memory and let the Shading correction active at the program exit.

Save SCM to File:
The current used SCM data will saved in a file as binary format.

Load File to SCM:
A stored reference signal will be loaded from a file into the SCM. After the loading process the Shading Correction is active.

If it not possible to grab an image of a white object the Natural Lens Vignetting can be used for raising the edge areas left and right.

5.8 White Balance for Color Line Scan Cameras

5.8.1   Shading Correction of a scanned white object

The aim of White Balance using Shading Correction is a homogeneous scaling of intensity, and additional the alignment of the R, G, and B signals so, that the three colors have the same intensity for a white object. The best results are obtained by scanning e.g. a white paper sheet in movement. The calculation of the correction is based on the averaged intensity profile of the surface scans. In this way, disturbing influences of the surface structure can be avoided.
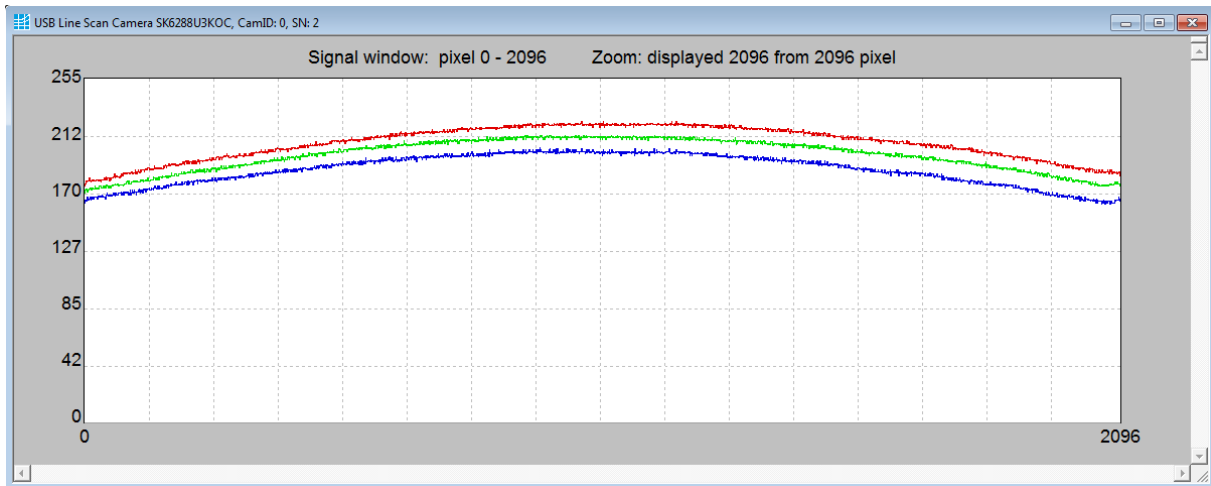
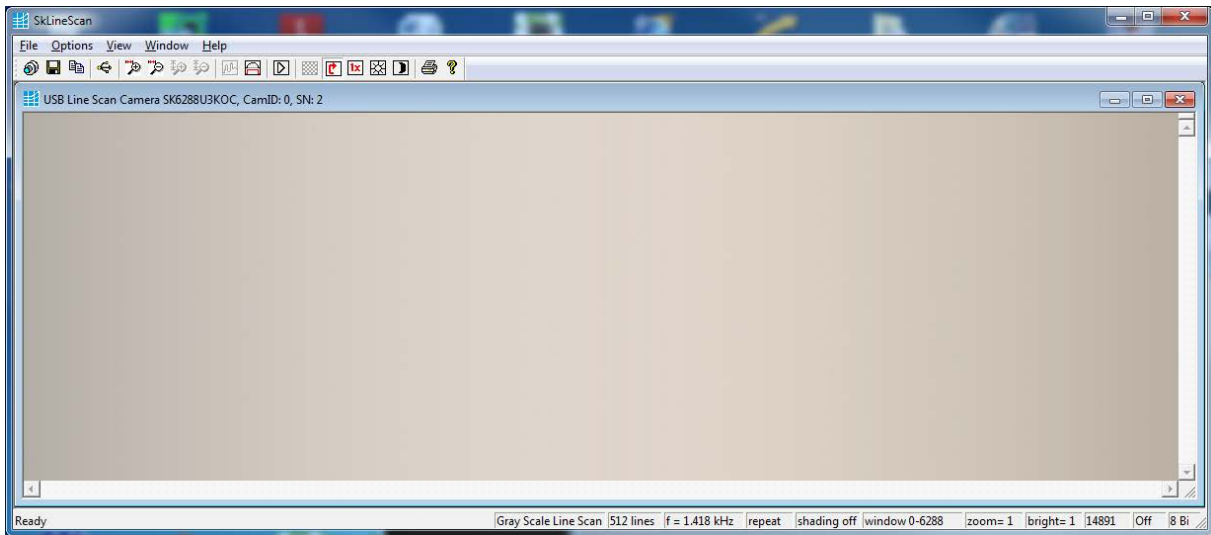*Fig. 24: RGB-Signal of a white paper sheet before Shading Correction*

Fig. 25: Area Scan of the moved white paper sheet in Fig. 22 before Shading Correction

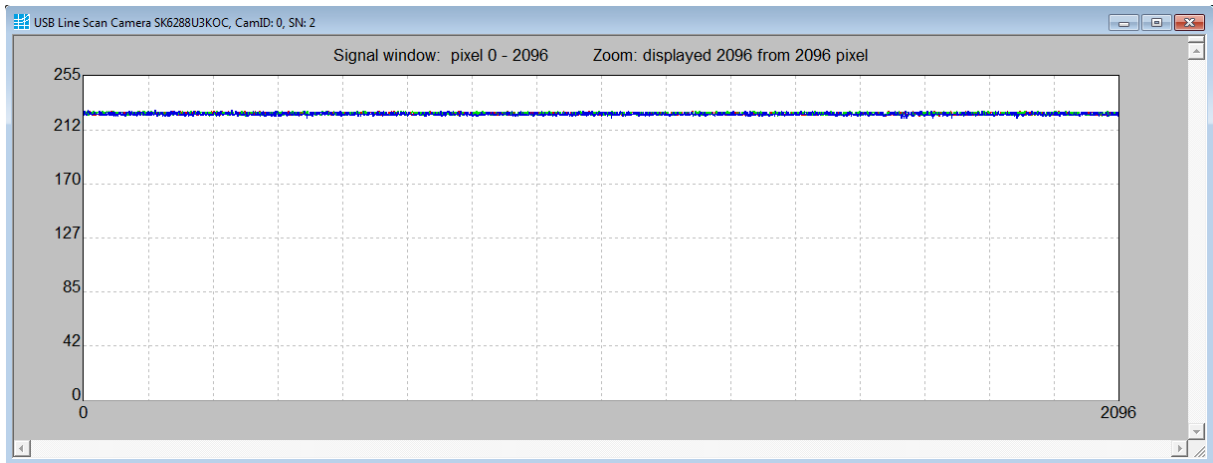*Fig. 26: Area Scan after Shading Correction*

Fig. 27: Line Scan signal after Shading Correction

5.8.2 Using Combination of Gain-Adjustment and Lens Vignetting Correction

Alternatively to the White Balance using the Shading Correction:

1. Adjust the gain of R, G, and B so, that the colors are overlapped.
2. Correction of Natural Lens Vignetting for increasing the intensities at the left and right side.

Especially it is usable, if it is not possible to scan a white object as reference area for the Shading Correction.

Using the gain sliders in the Gain/Offset dialog the RGB colors should be at the same level, assumed an object whith a homogenous white background.

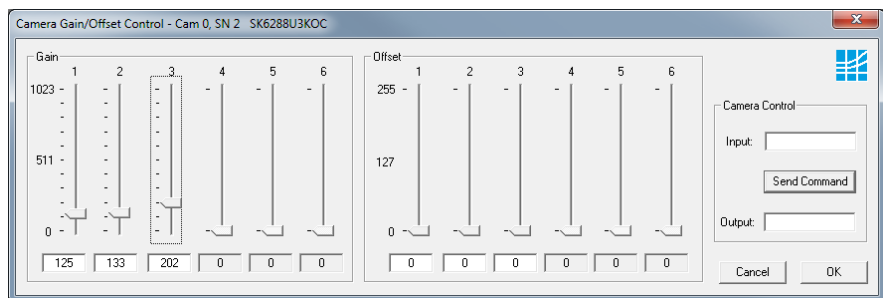The SK6288U3KOC camera has 1 gain/offset channel per color.
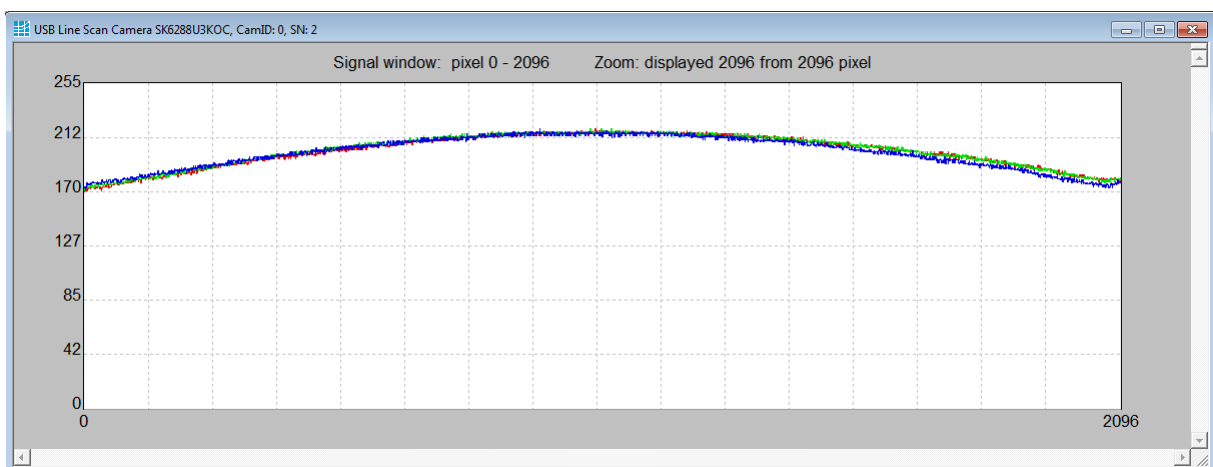

Fig. 28: Gain adjustments for R, G, and B

Fig. 29: Overlapped Line signals after gain adjustments for R, G, and B

Based on the formula for correction of Natural Lens Vignetting a theoretical correction profile will be calculated and used for Shading Correction.

Parameters for correction of natural lens vignetting:

FL =   Focal Length in mm
SL =   Sensor Length in mm
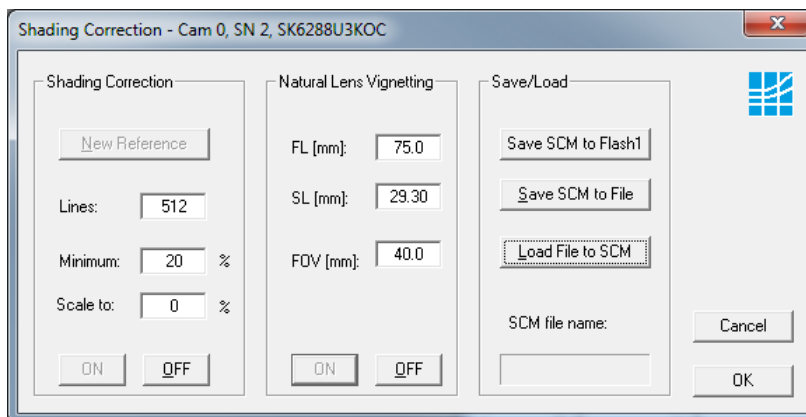FOV =   Field Of View in mm

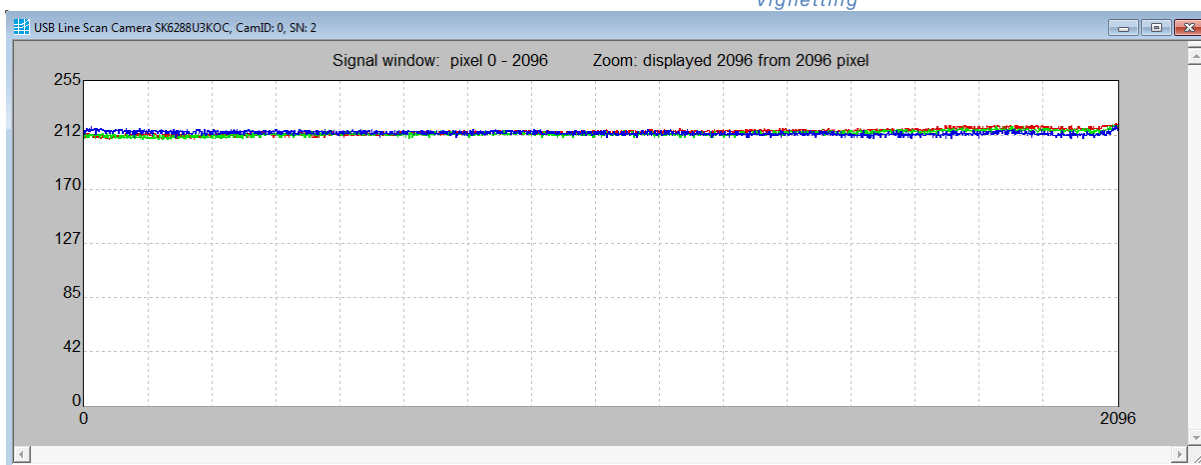*Fig. 30: Input parameters FL, SL, and FOV an press ON for correction of Lens Vignetting*

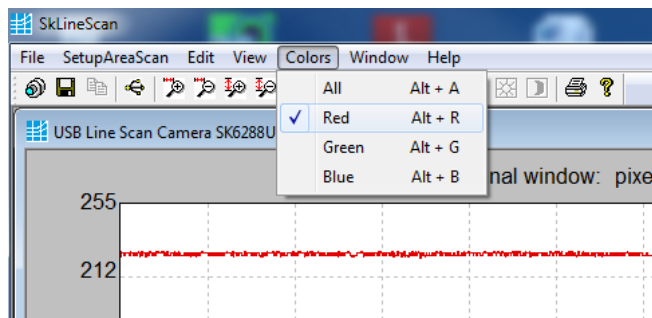*Fig. 31: Flat RGB Line Scan signals after Gain ajustment and Lens Vignetting Correction*

Fig. 32: Only red signal is display
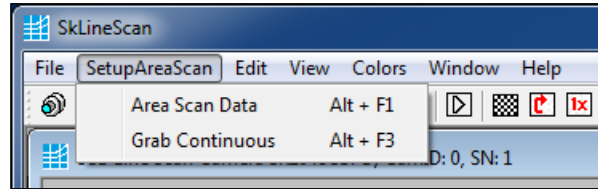
5.9 Performing an Area Scan

5.9.1 Setup Area Scan

The **SetupAreaScan** menu item **Area Scan Data** of the SkLineScan window enables the preparation of an area scan.

To open the dialog, use the following:
Hot Key: **[Alt] + [F1]**
Menu: **SetupAreaScan – Area Scan Data**

no. of Lines
This input defines the number of lines to acquire a 2-dimensional image. This is the image height. The image width is determined by the the pixel number of the sensor, or of the Region of Interest (ROI). The total image size in bytes is calculated by

image width x image height x bytes per pixel.

Timeout
The **Timeout** is the time after which a grab will be canceled, if an image is not complete by then.
The Timeout must be greater than

integration time x *no. of Lines*.

Thickness
This parameter affects the line thicknes in drawing the line signal in the oscilloscope display. The default value is 1.
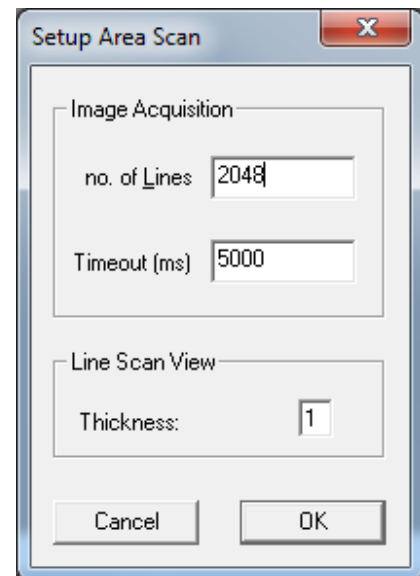
The single area scan function, started by **[F3]** or the *Area Scan* icon in the toolbar, acquires the complete image for the defined number of lines and this image is displayed (if all lines have been written to the PC memory).

5.9.2 Single Area Scan

To start the area scan call one of the following:
Hot Key: **[F3]**
Menu: **View** – **New Area Scan**
Toolbar Icon: ▨

The Single Area Scan acquires repeatedly 2-dimensional images using the programmed number of lines. If a scan is complete, the image is displayed immediately, and the next scan will be started.
It is possible to trigger the acquisition with external events by using LINE SYNC or FRAME SYNC.
The standard display mode is the stretch mode [s]. In this mode is the complete image displayed in the window with correct aspect ratio. To display details, the copy mode [s] is recommended. The image pixels are displayed unscaled 1:1. The window shows only a part of the complete image. The truncated partial image can be moved using the horizontal and vertical scroll bars.

To make a snap shot click on the icon 🔲.

Press 🔳 for go on in repeatly mode.

While the area scan is displayed repeatedly, adjustment of the camera parameters is possible. For this open the camera control dialog (see chapter 4.5). The changes of the parameters will be used for the next image.
The image can be saved as a file in bitmap or png format, or as raw data in txt or csv format.
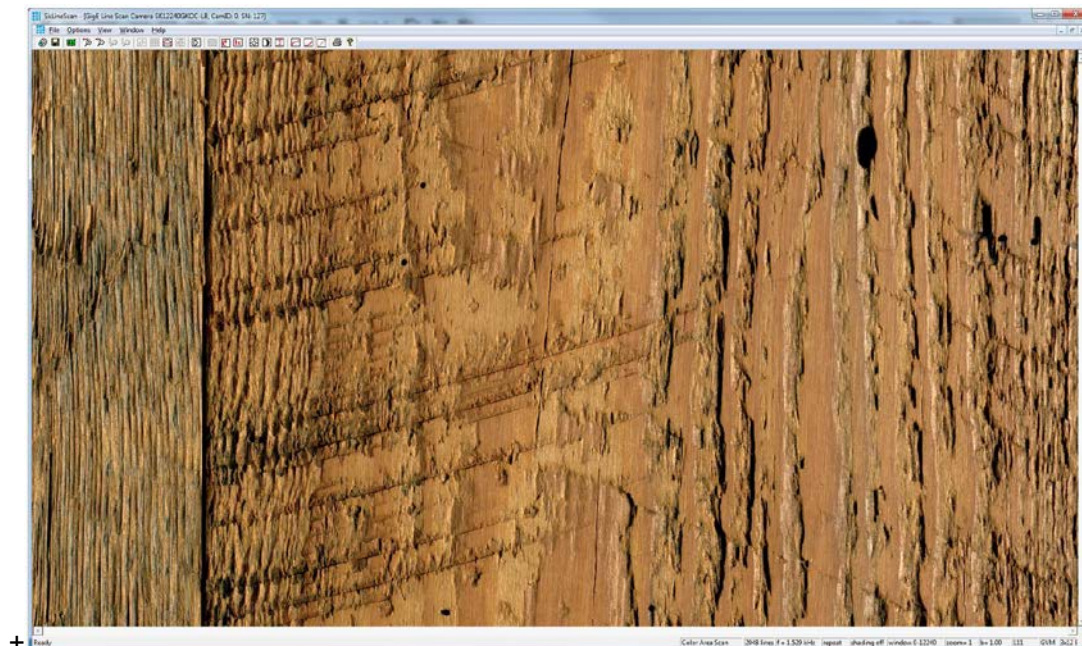

Fig. 33: Color area scan

5.9.3 Continuous Area Scan

In difference to Single Area Scan the Continuous Area Scan starts the image acquisition only one time at the beginning. Then the camera writes the video data without break into a ring buffer, consists of a programmable number of frames. The SkLineScan uses 10 buffers in a ring, which are installed before the Continuous Mode starts. The ring buffer will be written cyclical by the camera until the user stops the acquisition. Intern, the driver DLL signals the SkLineScan program if a frame is completely. The last grabbed frame will be displayed immediately.

With the SDK the user can request the last acquired image and copy the image data to a local memory. It is also possible to access the image data directly by installing a user managed buffer queue.

The advantage of the continuous grab is, that the overhead at the beginning of image acquisition, which takes normally 0.028 ms to 2 ms, will be run only once. After the start no further commands must be sent. While one frame is displayed or analyzed, the camera writes video data in the next frame of the ring buffer. Thus, a continuous image processing and evaluation is possible without time limit.

To start the continuous area scan, do the following:
Hot Key: **[Alt] + [F3]**
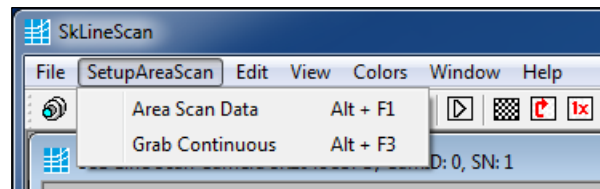Menu: **SetupAreaScan** – **Grab Continuous**

then

Hot Key: **[F3]**
Menu: **View** – **New Area Scan**
Toolbar Icon: ▦

The adjustment of the camera parameter is not possible while the camera works in Continuous Mode.

5.9.4 Save Image

A grabbed area scan can be stored as a image in png or bitmap format, or as raw data. In the raw data format the pixels will be saved, separated by semicolon, in txt or csv file.
The saving of the image as PNG-format is recommended. The PNG-format is a lossless compression.

Fig. 34: Save area scan as image or raw data

To save the data as raw data, use the following :
Hot Key: **[Ctrl] + [S]**
Menu: **File** – **Save Data**

To save the data as image:
Hot Key: **[Ctrl] + [Alt] + [S]**
Menu: **File** – **Save Bitmap**
Toolbar Icon: 💾

5.9.5 Area Scan View Options

In the area scan view exits the menu item **View**. This menu item contains functions to manipulate the view of area scan images.
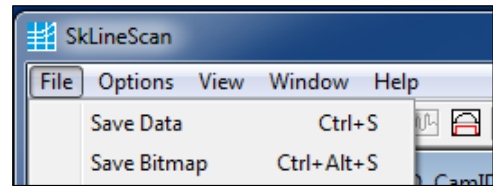
Flip Horizontal ([Alt] + [H]), Flip Vertical ([Alt] + [V])
This functions mirror the image around the x axis and/or around the y axis. These operations are performed by software and increase the CPU load.

Bright up, Bright down
The functions increase / decrease the pixel intensity of a grabbed image by a fixed factor of 0.25 and affects the image brightness. The current factor is displayed in the status bar. E.g. :

b= 1.50

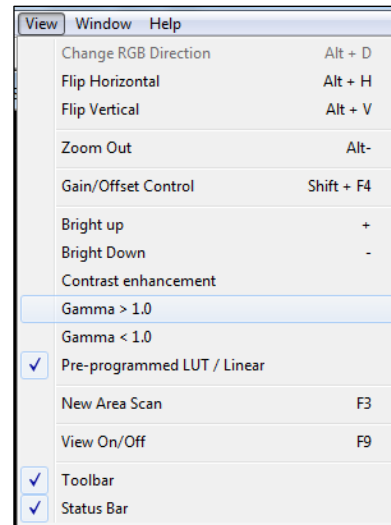Note, that for display a unchanged image the factor must be 1.0.

Fig. 35: Menu item View in area scan view

Change RGB Direction

For a perfect RGB matching color line scan cameras with Triple-Line-Sensors need a preferred transport direction of the scanned object, or of the camera. A wrong direction causes convergence errors in color (s. Fig. 18).
This function sorts the RGB pixels in the memory so, that also at a wrong transport direction the view is correct.

Fig. 36: Monochrome font pattern with line synchronous object pattern (good) and asynchronous transport of the object (bad - causes color convergence aberration)

Contrast enhancement

Based on the histogram analysis the contrast will be optimized by the software.

Gamma function, Linear LUT

This functions affect brightness, contrast, and dynamic range in the image. The correction profiles are calculated by using parameters in LUT Programming dialog, and will be written in the Lookup Table of the camera. The correction operations are done inside the camera, so they don't burden the CPU.

6 Error-Code Table

Error Name	Value (Dez)	Value (Hex)
SK_RESULT_OK	0	0x00
SK_RESULT_ABORTED	1	0x01
SK_RESULT_ARGUMENT_TOO_LONG	2	0x02
SK_RESULT_BAD_ADDRESS	3	0x03
SK_RESULT_BUFFER_TOO_SMALL	4	0x04
SK_RESULT_CANNOT_CREATE_EVENT	5	0x05
SK_RESULT_CANNOT_OPEN_FILE	6	0x06
SK_RESULT_CANNOT_SET_EVENT	7	0x07
SK_RESULT_CONSTRUCTOR_FAILED	8	0x08
SK_RESULT_CORRUPTED_FILE	9	0x09
SK_RESULT_DEVICE_ERROR	12	0x0C
SK_RESULT_DEVICE_RESET	13	0x0D
SK_RESULT_DRIVER_ERROR	14	0x0E
SK_RESULT_IMAGE_COMPLETED	15	0x0F
SK_RESULT_FILE_ERROR	16	0x10
SK_RESULT_INTERNAL_ERROR	17	0x11
SK_RESULT_INVALID_ARGUMENT	18	0x12
SK_RESULT_NETWORK_ERROR	19	0x13
SK_RESULT_NO_AVAILABLE_DATA	20	0x14
SK_RESULT_NO_MORE_ITEM	21	0x15
SK_RESULT_NO_SELECTED_ITEM	22	0x16
SK_RESULT_NOT_CONNECTED	23	0x17
SK_RESULT_NOT_ENOUGH_MEMORY	24	0x18
SK_RESULT_NOT_FOUND	25	0x19
SK_RESULT_NOT_SUPPORTED	26	0x1A
SK_RESULT_OVERFLOW	27	0x1B
SK_RESULT_STATE_ERROR	28	0x1C
SK_RESULT_THREAD_ERROR	29	0x1D
SK_RESULT_TIMEOUT	30	0x1E
SK_RESULT_UNDERFLOW	31	0x1F
SK_RESULT_UNEXPECTED_ERROR	32	0x20
SK_RESULT_UNEXPECTED_EXCEPTION	33	0x21
SK_RESULT_UNKNOWN_ERROR	34	0x22
SK_RESULT_UNSUPPORTED_CONVERSION	35	0x23
SK_RESULT_OPERATION_PENDING	36	0x24
SK_RESULT_IMAGE_ERROR	37	0x25
SK_RESULT_CORRUPTED_IMAGE	38	0x26
SK_RESULT_MISSING_PACKETS	39	0x27
SK_RESULT_NETWORK_LINK_DOWN	40	0x28