Manual

VLS Software Image Engineering GmbH & Co KG

Translated from the German manual version 0010

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Trade name: **VLS-Software**
Product name: **VLS-Software**

Product number: **100400111**

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Contents

1 About these operating instructions

You must read these operating instructions before operating the VLS software for the first time or if you are tasked with any other work using the VLS software.

Pay particular attention to **Chapter 2, "General safety regulations"**.

1.1 General information

These instructions are intended to simplify the VLS software and ensure it is used for its intended purpose.

The operating instructions contain important information on the proper use and safety of the VLS software. Observing them will help:

- Avoid dangers
- Reduce repair costs and downtime
- Increase the reliability and service life of the product

Everyone working on the VLS software must read and apply these instructions.

In addition to these operating instructions, the accident prevention and environmental protection regulations applicable in the country of use and the place of use must also be observed.

1.2 Further documentation

- Vega operating instructions
- P2020 definitions of the calculated standards (release/pre-release)

1.3 Presentation of information

Structure of instructions

Instructions for action are divided into:

- Action steps
- Results of the actions
- Application tips for optimal use

A symbol identifies each piece of information:

Icon	Meaning
1. 2. 3.	Action steps: These action steps are numbered consecutively and must be carried out in the specified order from top to bottom.
✓	Result symbol: The text after this symbol describes the result or intermediate result of an action.
TIP:	Application tip: Additional information on optimal use of the product.

Tab. 1.1 Meaning of symbols

Structure of the warnings

Signal word	Use with ...	Possible consequences if the safety instructions are not observed:
DANGER	Personal injury (imminent danger)	Death or serious injury!
WARNING	Personal injury (potentially dangerous situation)	Death or serious injury!
CAUTION	Personal injury	Slight or minor injuries!
NOTE	Material damage	Damage to the device and the surrounding area

Tab. 1.2 Warning levels

The warnings are structured as follows:

- Warning sign with signal word corresponding to warning level
- Type of hazard (description of the hazard)

- Hazard consequences (description of the consequences of the hazard)
- Averting danger (measures to prevent danger)

DANGER!

Type of hazard

Consequences of danger

1. Emergency response

Warning signs

Special warnings are provided at the relevant points. They are marked with the following symbols.

General danger zone
This sign warns of personal injury.

2 General safety regulations

2.1 Principles

Important:
Read the instructions carefully before using the software.
Incorrect use of the product can lead to incorrect measurements.
Always keep the instructions and pass them on to new product users.

2.2 Intended use

The VLS software is split into a control software and an evaluation software for Windows platforms.

The control software is intended to control light sources to illuminate test charts. It supports the calibration of 6 Vega light sources equipped with TE294 test charts. A seventh Vega kann be used to help in alignment.

The setup as described allows the user to create calibrated recordings of specific luminance values and use them for the characterization of the imaging system under test.

For optimal results the calibration and recording need to be done in a darkened room.

The evaluation is intended to evaluate the recorded images in regards several image or video quality metrics.

The appliance may only be operated indoors.

2.3 Foreseeable misuse

NOTE:

Use with Image Engineering DTS

This software must not be used in combination with Image Engineering DTS hardware.

NOTE:

Use of other Image Engineering light sources

This software may not be used with other light sources, only Image Engineering Vega light sources.

NOTE:

Use of several Vega controllers or more than seven light sources

This software must not be used with more than one Vega controller or seven light sources.

2.4 Safety regulations

General information

Regularly check the cabels in use for damage and replace damaged cables immediately. If any damage exists do not use the device, and disconnect it from the electrical grid.

Do not directly look at active light sources. Especially in darkened environments.

Personal protective equipment

As the Vega light source is classified under risk group 0 with regard to IEC 62471:2006, the user does not need to wear personal protective equipment.

During commissioning

NOTE!

Observe all safety instructions and the operating instructions for the hardware used.

During operation

WARNING!

Photosensitive epilepsy

When playing back measurement sequences, the Vegas flash with high intensity to distinguish individual measurement sequence elements from one another.

When playing back "MMP" measurement sequences, the Vegas may flash with high intensity and different frequencies.

This flashing can cause discomfort or photosensitive epilepsy in sensitive people.

When reproducing sequences, the view should be averted from the light sources.

The use of the device is not recommended for people with a tendency to epilepsy.

CAUTION!

Risk of tripping

When routing cables, ensure that passageways are clear of cables (mains cable, USB, etc.). Ideally, use cable ducts.

CAUTION!

Glare

The Vegas sometimes light up with high intensity when playing back measurement sequences and for calibration.

For absolute calibration, the user should position themselves to the side of the light sources for the measurement. Avoid looking directly at the illuminated surface.

When reproducing sequences, the view should be averted from the light sources.

NOTE!

Risk of cable breakage

When routing cables, especially USB cables, ensure they are not stepped on and are laid firmly in cable ducts to avoid cable breaks.

2.5 Selection and qualification of personnel

There are no special qualification requirements for operating the device. However, the personnel must be familiar with these operating instructions, especially the safety instructions.

2.6 Workstations for the operating personnel

A dark room with black walls and less than 1 lux residual light is required.

2.7 Safety devices

This software product does not require a safety device.

2.8 Safety signs

There are no safety signs on the associated devices.

2.9 Software terms of use

Modifications to the software are not permitted. The terms of use enclosed with the software apply.

2.10 Fire protection

No special fire protection requirements exist for operating the software on standard PCs.

Fire fighting

Disconnect the affected appliances from the power supply and follow the local fire safety instructions if possible.

2.11 Actions in an emergency

In case of an emergency caused by the illumination of the light sources, turn them off immediately.

Call for help and apply first aid if possible. Call a doctor if necessary. Follow local emergency instructions.

2.12 Accessories + compatibility list

- Vega Light Sources
- Vega Controller
- TE294 Vega chart
- Calibration plate for TE294 Vega Chart
- ND-Filter for Vega Light Source
- PRC Krochmann Radiolux 111 Photometer / Radiometer
- VLS Tube for Radiolux 111

3 Operating software

3.1 Overview

Software

VLS software is divided into two components.

- **VLS-Control** generates hardware control sequences that can be played back on supported devices. During playback, a reference file is generated from previously measured calibrations and real-time measurement values, which can be used to evaluate image sequences. The calibration workflows are part of VLS-Control.
- **VLS-Evaluation** calculates all relevant "Key Performance Indicators" (KPIs) from recorded image sequences of the device under test and the reference file generated by VLS-Control

System requirements/limits

- PC with Windows 10
- 2 USB ports for the Vega controller and calibration devices
- Recommended:
  - 16 GB working memory
  - 13th Gen Intel(R) Core(TM) i7-13700H or comparable

Installation

Execute the installation file(s) for VLS-Control and VLS-Evaluation. Drivers for compatible light sources and the following additional software are installed:

- Microsoft Visual C++ Redistributables

Workflow

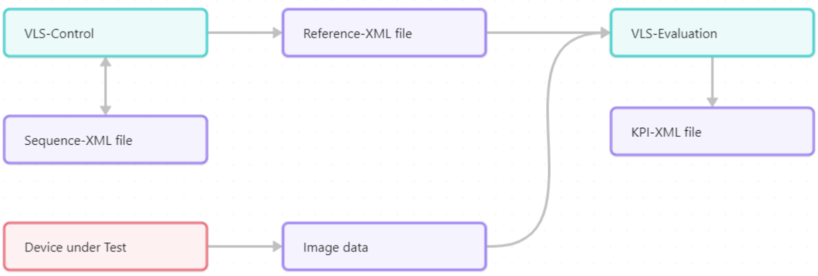


Figure 1 Typical workflow Green: Software Purple: File formats, Red: User's device

3.2 VLS-Control

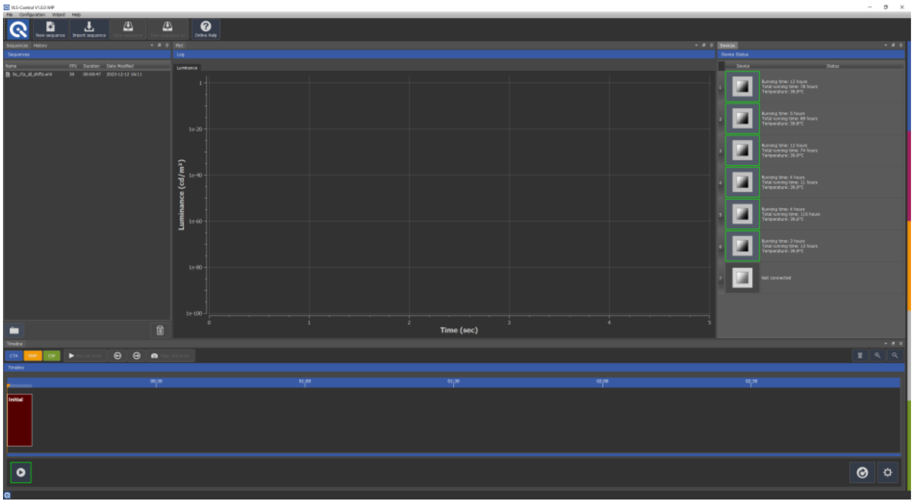


Figure 2 Main window of the VLS-Control Software

The VLS-Control software is executed on a computer connected to the necessary hardware (light sources, calibration devices).
Before starting a measurement or calibration wait 2 minutes until the Vega light sources have reached their working temperature.

Device status and control

After starting the VLS-Control software, it immediately attempts to connect to the supported devices and checks their functionality. All correctly connected devices are highlighted in green in the Device Status panel. If a device is not recognized, please contact Image Engineering for support.

Calibration

There are several calibration routines for the devices supported by VLS:

Calibration	**Calibration period**	**Necessary equipment**
CTA: Sensor initialization	Before each absolute calibration	-
CTA: Relative calibration	Every three months, regardless of use	Krochmann Radiolux 111 with VLS tube or other Class L luxmeter with an aperture diameter of 8 mm

		and an outer tube diameter of 12 mm
CTA: Absolute calibration	Every 50 operating hours	Krochmann Radiolux 111 with VLS tube or other Class L luxmeter with an aperture diameter of 8 mm and an outer tube diameter of 12 mm
CTA: Rescaling the light sources	After each absolute calibration	-

The control software will inform you about the necessary calibrations:

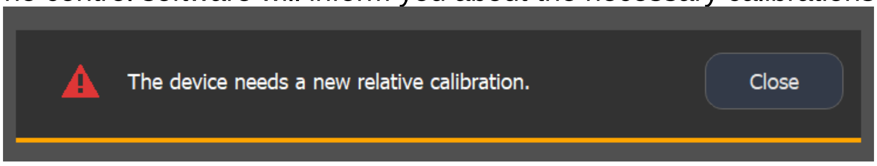


Figure 3 Calibration warning

Vega sensor initialization
Internal sensors measure the status of each Vega light source. These must be initialized before each absolute calibration.

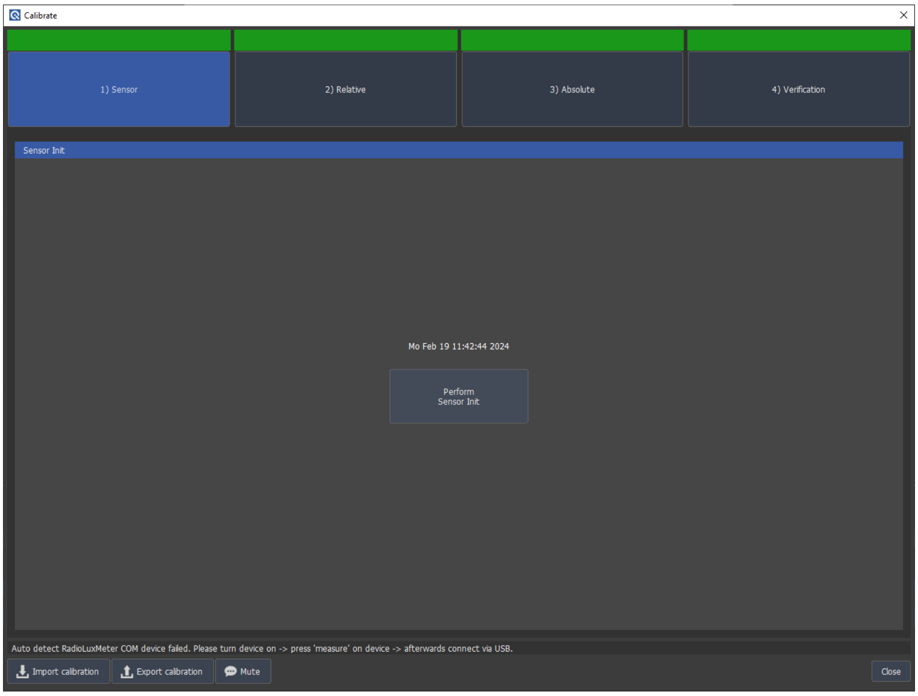


Figure 4 Sensor initialization

Ensure the room is darkened and no light shines on the Vega light sources. Then press the button labeled "Perform Sensor Init." This procedure can take up to two minutes. Do not turn on any lights until initialization is complete.

The initialization invalidates the existing absolute calibration and thus must be performed again.

TE294 Chart Relative Calibration

The TE294 charts on a Vega light source must be recalibrated every three months ("relative calibration").

The application informs you when a new relative calibration is required. All patches to be measured can be seen in the Calibration dialog. Measurements that have not yet been measured or have expired are marked with a red warning symbol. Patches whose measured value does not match the expected brightness ordering of the chart are marked with a yellow warning symbol.

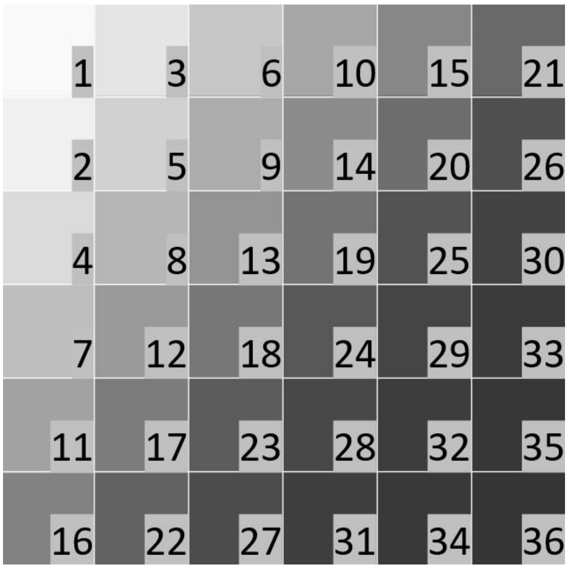


Figure 5 Patches enumerated by descending brightness

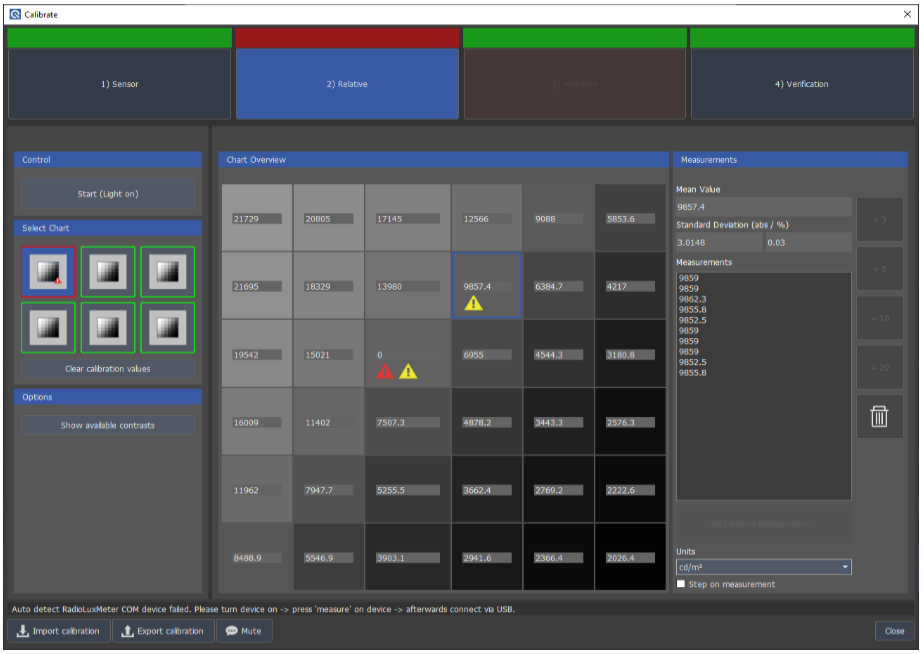
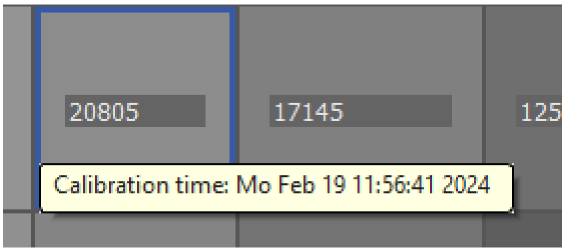


Figure 6 Incomplete relative calibration

If you click on a patch or hold the mouse pointer over it, the time of the last measurement is displayed.



Calibration can be carried out with any L-class lux meter, but the workflow has been designed around the "Radiolux 111 Class L Luminance Meter." This workflow makes the calibration process much quicker and more convenient.

The relative calibration determines the distribution of luminance across each CTA chart.

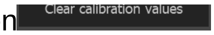
It should be noted, however, that this does not determine the absolute luminance of the Vegas.

With absolute calibration, the Vega displays different luminance levels. When measuring with the Radiolux 111, make sure that you measure with the VLS tube.

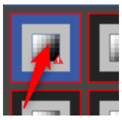
Sequence of the calibration process:

- Open the calibration dialog

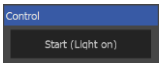
- Switch on the Radiolux 111.
- Connect the Radiolux 111 via USB to the computer on which VLS-Control is running.
- The Radiolux should automatically switch to the measurement menu. VLS-Control now controls the Radiolux. If you want to measure manually, temporarily disconnect the USB connection.

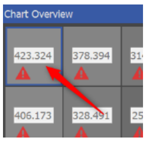
- Press the button 

to delete the measurements in the current chart.
- Darken the room.
- Place the calibration plate on the first chart.
- Wait until the Vega light sources have been running for at least 2 minutes so they can reach their working temperature.
- Select the first chart in the dialog.



- Press the button to switch on the light source
- Select the first patch of the chart.





- Place the measuring head on the first patch.
- Press one of the buttons  ...  to start a new measurement. The number on the button determines the number of individual device measurements.
- Alternatively, the right arrow can be used to measure five values.
- If the "Step on measurement" box is checked, the measurement process automatically switches to the next patch.
- After the measurement, the software displays the averaged measured value. If this is not desired, the software can be muted. The individual values of the selected patch can be seen in the value list on the right-hand side of the dialog.
- The measuring head can now be removed from the patch.
- Proceed similarly with the other chart patches and repeat the process with the different charts.
- If the measurement of a patch is inaccurate, the measured values can be deleted using the button with the recycle bin symbol.

When using an alternative luxmeter, use the "Add Manual Measurement" button to enter a manual measurement.

When all red warning symbols have disappeared, all measurements have been completed.

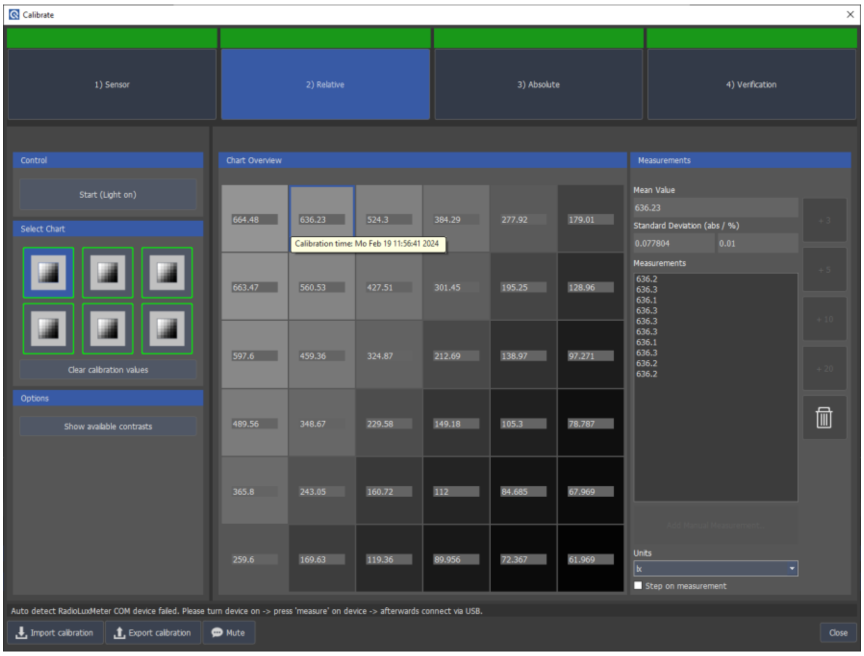
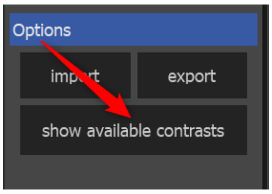


Figure 7 Completed relative calibration

After the relative calibration, you can see which contrasts can be re-solved under ideal conditions. To do this, use the "Show available contrasts" button:



By default, the contrast curve of all possible CTA steps is displayed here.

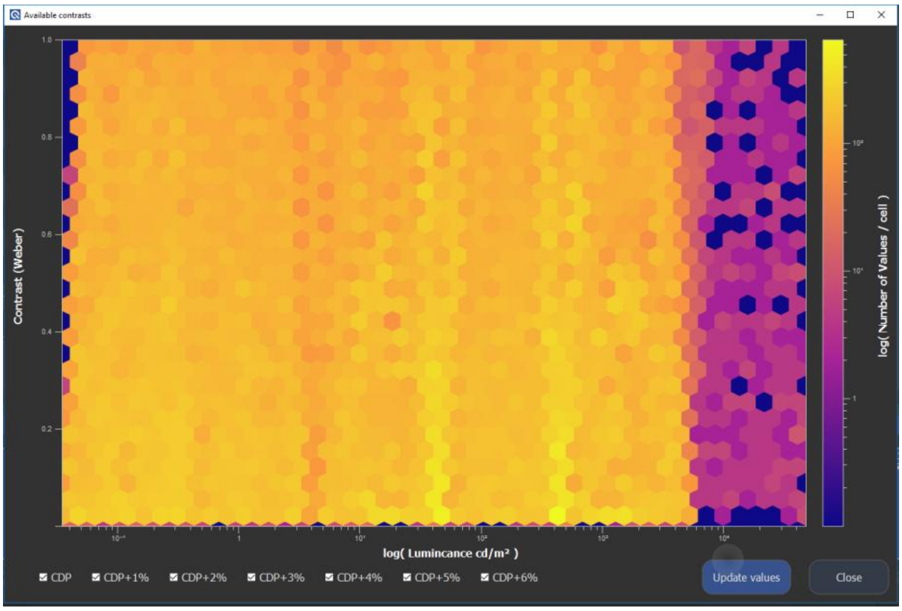


Figure 8: Available contrast values

If desired, the contrast curve can also be viewed for individual steps. If necessary, absolute calibration follows.

CTA Absolute calibration

An absolute calibration is necessary after every 50 hours of operation.

The application informs you when the calibration needs to be carried out. The runtime can be read in the device list in the main window.

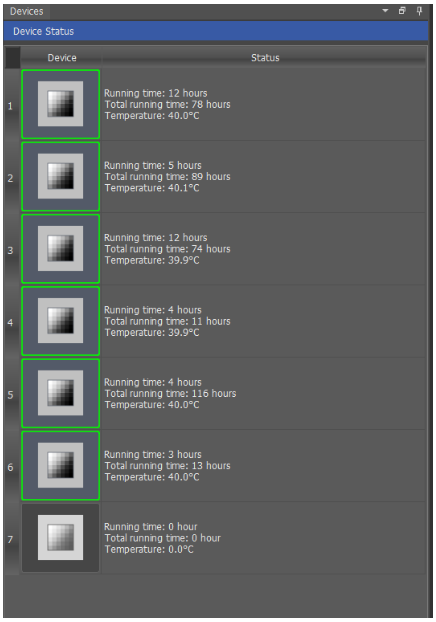
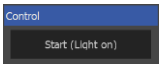


Figure 9: Running time of the light sources

Calibration can be carried out with any L-class lux meter, but the workflow has been designed around the "Radiolux 111 Class L Luminance Meter." This workflow makes the calibration process much quicker and more convenient.

The absolute luminance calibration determines the absolute luminance per Vega and CTA chart.

- Darken the room
- Open the calibration dialog
- Carry out the sensor initialization if you have not already done so (first tab in the calibration dialogue)
- Open the tab for absolute calibration.
- Select the first chart in the menu. Only the brightest patch must (and can) be measured here.
- Place the calibration plate on the chart
- Wait until the Vega light sources have been running for at least 2 minutes so they can reach their working temperature.
- Press the button to switch on 

 the light source

- The first Vega light source is almost at maximum brightness during calibration. Perform the measurement by moving the measuring head from the side of the light source to the top left corner of the measuring plate.

- Place the measuring head on the brightest patch.
- Press one of the buttons 

 ... 

 to start a new measurement. The number on the button determines the number of individual device measurements.
- Alternatively, the right arrow can be used to measure five values.
- After the measurement, the software displays the averaged measured value. If this is not desired, the software can be muted. The individual values of the selected patch can be seen in the value list on the right-hand side of the dialog.
- The measuring head can now be removed from the patch.
- If the measurement of a patch is inaccurate, the measured values can be deleted using the button with the recycle bin symbol.
- Measure in the same way using the other light sources.

Once all light sources have been measured and you are satisfied with the measurements, complete the "Rescale lightsources" step.

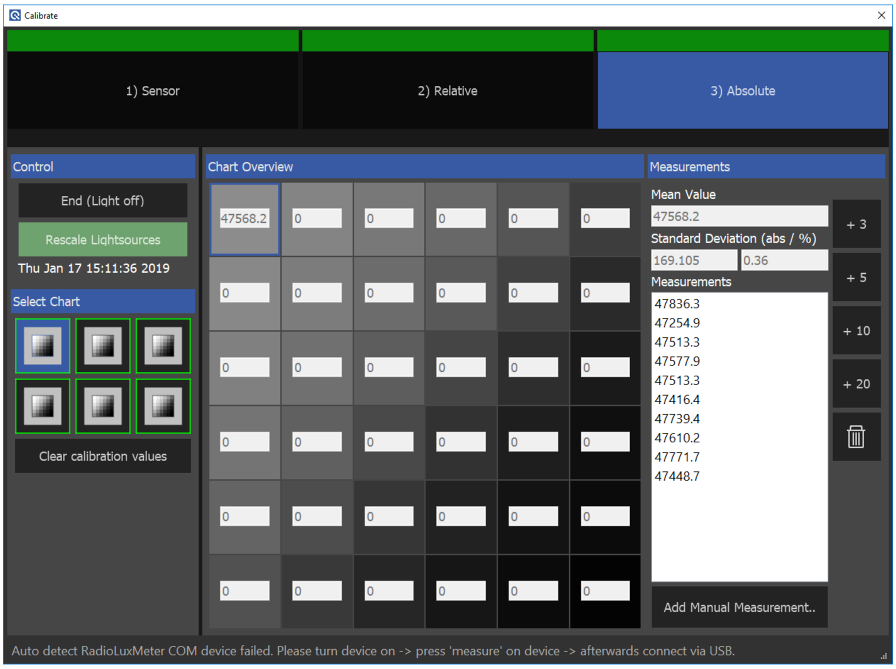


Figure 10: Successful absolute calibration

Verify calibration

The existing absolute calibration can be verified in the "Verification" tab. The calibration measured values, the internal device measured values, and the measured values of the Radiolux are displayed here. Select the "Start (Light On)" button to verify the light source and switch it on.

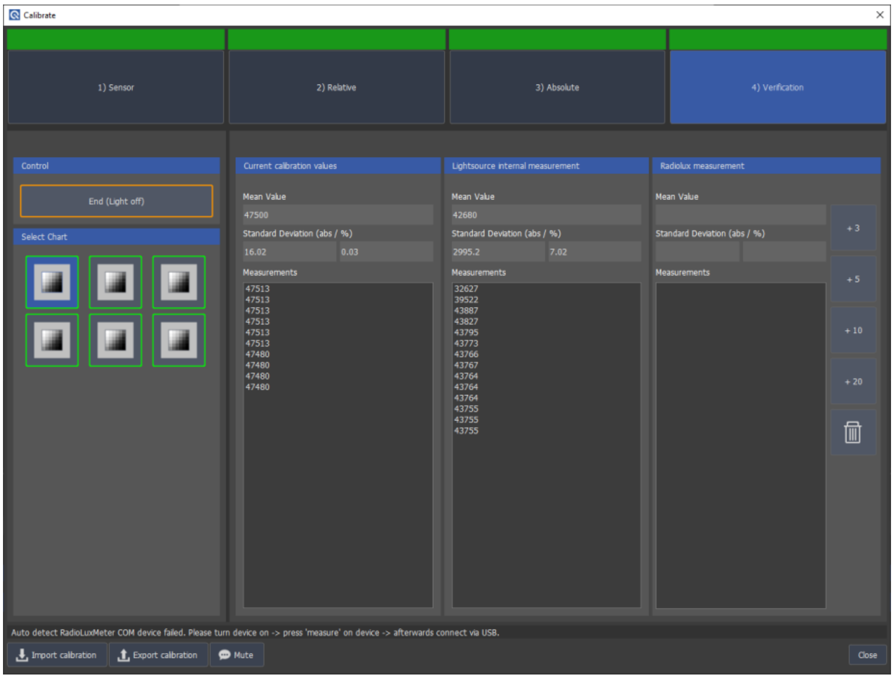


Figure 11: Verification of the calibration

Rescaling the light sources

Once the absolute calibration measurement has been completed, the light sources must be rescaled. To do this, darken the room and click the "Rescale Lightsources" button.

Be patient; rescaling takes up to 2 minutes.
Only switch the light on when the "Please Wait..." display has disappeared.

Sequence generation

Figure 12 Screenshot of the sequence generation

In the VLS-Control software, the user can create sequences to be played back on the connected devices. The sequences are saved as an XML file for reuse.

Sequence settings

In addition to the sequence, some metadata can be defined in the VLS Control software, which displays or automatically pauses the sequence.

Frame rate: The timeline in which the sequence is displayed supports both seconds/minutes and frames as a time unit. The camera's frame rate must be specified to display the correct number of frames.
Frame size: Playback can be paused automatically for devices with limited memory. The individual frames' frame rate and size must be specified to achieve this.

Step introduction and ending time: A flashing sequence must be played before and after each sequence element. The sequence duration should be approximately 30 frames (e.g., 500 ms for 60 FPS, 1000 ms for 30 FPS).

Initial step duration: At the start of the sequence, all light sources display the same brightness for this duration.

Snap to grid: If this option is activated, the objects in the timeline are aligned to the displayed grid.

Sequence element parameters
Sequence elements each have their own parameters, which can be changed for each sequence element.

Sequence elements

CTA
The Contrast Transfer Accuracy is measured using several images of six Vega light sources, each with a chart consisting of 36 different neutral density filters.
The CTA measurement using VLS-Control Software is a spatial CTA measurement, due to multiple luminances being evaluated from on image.
These allow a stable reproduction of luminances from 0.05 to 50,000 cd/m². This range corresponds to a ratio of one in a million or six decades. For the correct evaluation of the 216 different brightnesses of the patches, as many images as possible must be taken to obtain a stable distribution of values per patch.
To further increase the CTA measurement's resolution, the Vegas intensities can be increased in 1% steps up to 6% (One brightness step in the chart corresponds to slightly more than 6%). If the brightest light source already operates at maximum intensity, it will not increase by the expected step.
While the Sequence element is called CTA, the generated data is also used for additional Contrast Metrics like CSNR, CNR, and DR.

MMP
MMP elements are used to create flicker effects with the Vega light sources. The flicker frequency can be configured within the 10-1000 Hz range. The flicker duty cycle is adjustable from 1%-99%. It is also possible to set a phase shift in degrees per time in the range of 1°-359° so that the flicker phase shifts with the configured value after the selected time period has elapsed.

Sequence creation
The individual sequence elements can be inserted into the timeline using drag-and-drop. The properties of the sequence elements can be adjusted by right-clicking.

In the file overview, you can find previously used sequences or open the folder in which the files are located.

VLS-alignment

Place the device to be tested on a stable mount in front of the Vega light sources so that the optical axis is aligned orthogonally to the center of the light sources.

CTA

For optimum evaluation of CTA, try to adhere to the following criteria during alignment:

1. Each of the 36 patches per chart must take up at least 10x10 pixels in the image.
2. Allow as little scattered or reflected light as possible to fall on the Vega light sources. Avoid this, mainly for the darker light sources.
3. The test charts should be displayed as square as possible and parallel to the edge of the image in the camera image.

Manual lighting

Using the “Manual Light” and “Reflection Test” buttons you can test the light sources on functionality and alignment.
The “Manual Light” button turns on the 6 Vegas which are equipped with a CTA-Chart (CAN ID 1-6). If calibrated correctly, all charts should be at approximately the same brightness.
Th “Reflection Test” button controls the Vega with CAN ID 7 (if connected).
You can use it to find out at which brightness your Camera or Sensor goes into overexposure or if there are any unwanted reflections within the setup.

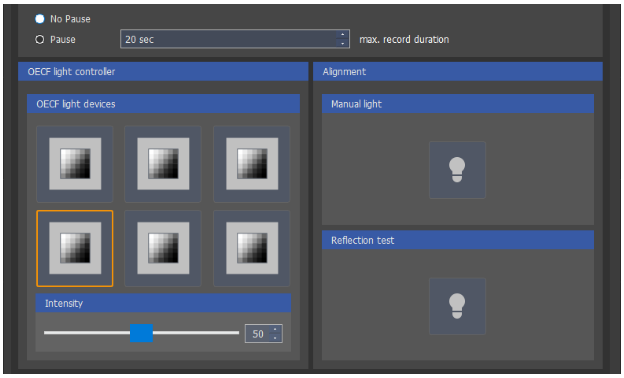


Figure 13: Manual control of the light sources

OECF light Controller

Individual Vega modules can be switched on and off in the "OECF light controller" panel. The intensity controller controls the intensity of the selected Vega. The manual settings here are only to assist when setting up the test stand and have no influence on the brightness displayed during the test.

Automatic pause of playback at recording limit

Most cameras have a limited memory for recordings. You can, therefore, set a recording limit, which pauses playback of the sequence when this limit is reached. While the sequence is paused, you can read the data from the camera and resume playback as soon as the camera is ready again.

Figure 14: "Automatic pause" settings panel

Plot of the reference values

The control software displays a detailed plot of all Vega-internal measured values during playback. The values are written in the reference file, as shown here.

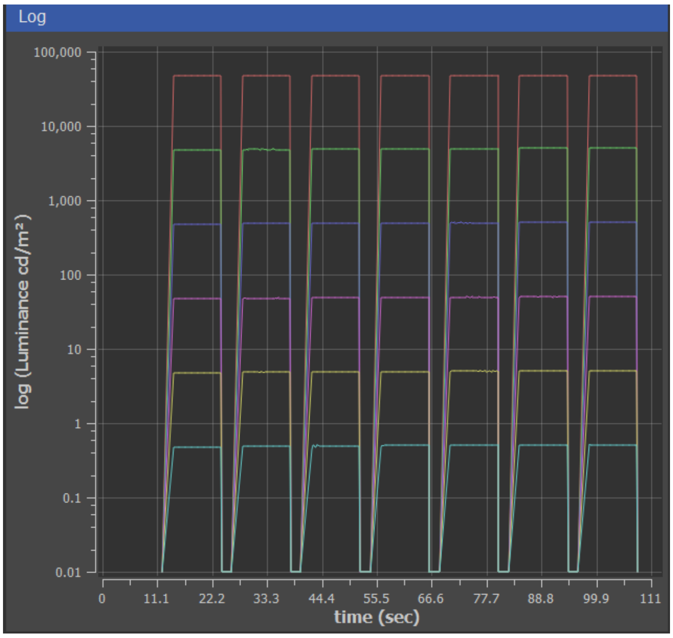


Figure 15: Live plot of the CTA measurement data

The display supports zooming and panning by scrolling with the mouse wheel or left-clicking in the window.

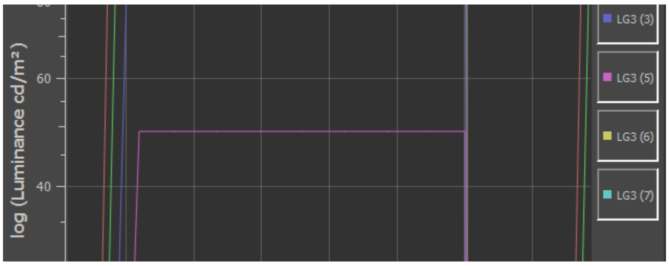


Figure 16: Zoom function of the plot

Individual graphs can be selected for display.

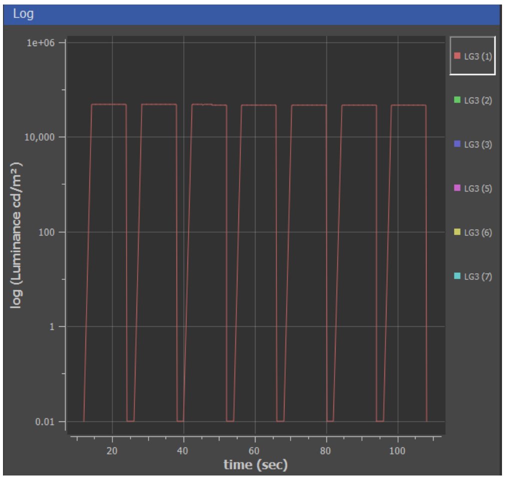


Figure 17: Activated filter to display individual graphs

Sequence playback

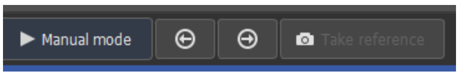


Figure 18 Control elements for manual playback mode

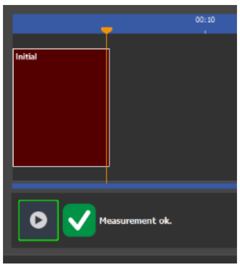


Figure 19 Automatic sequence playback

VLS-Control supports two different modes of sequence playback:

1. **Automatic:** Automatic mode is intended for cameras with a consistent frame rate of over 15 FPS. To play back the sequence, simply press the play button. The software automatically records reference values of the light sources during playback. It reproduces a flashing pattern between the sequence elements, automatically assigning the images to the individual sequence elements.

2. **Manual:** Manual mode is intended for cameras without a consistent or with a very low frame rate. Here, the arrows allow you to step from one measurement step to the next. Take at least four images of the Init element so the charts can be easily recognized later in the evaluation software.

   Then, switch to the next sequence element (right arrow) and click on the "Take reference" button once for each image the camera captures. Repeat this step until the end of the sequence.

Reference file

The luminance of the Vegas is measured during playback of the sequence and written to a reference file at the end of the sequence. This reference file is used with the recorded image data for the evaluation.

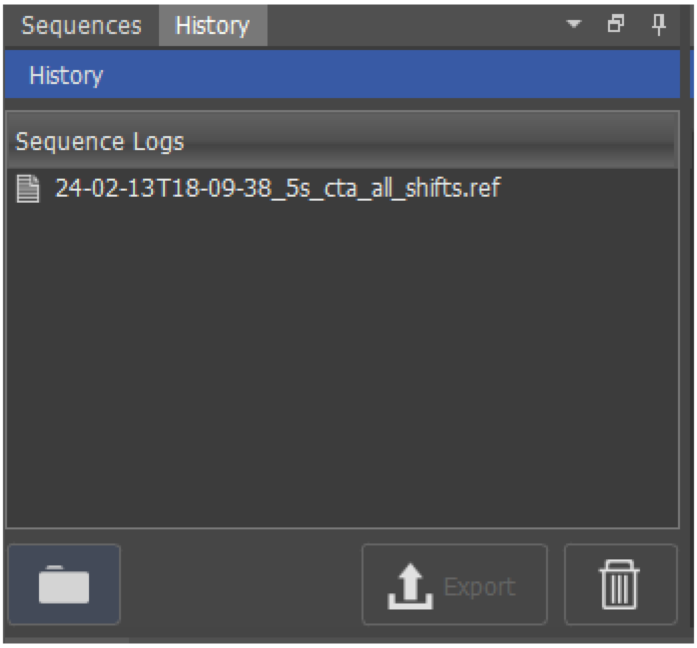


Figure 20 List of reference files

Checking the measurement

After the sequence has been completed, it is displayed whether the measured values of the Vega are valid.

If a problem occurs during the measurement, a message is displayed. In this case, it is recommended that the measurement be repeated.

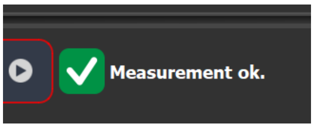


Figure 21 "Measurement OK" message

3.3 VLS evaluation

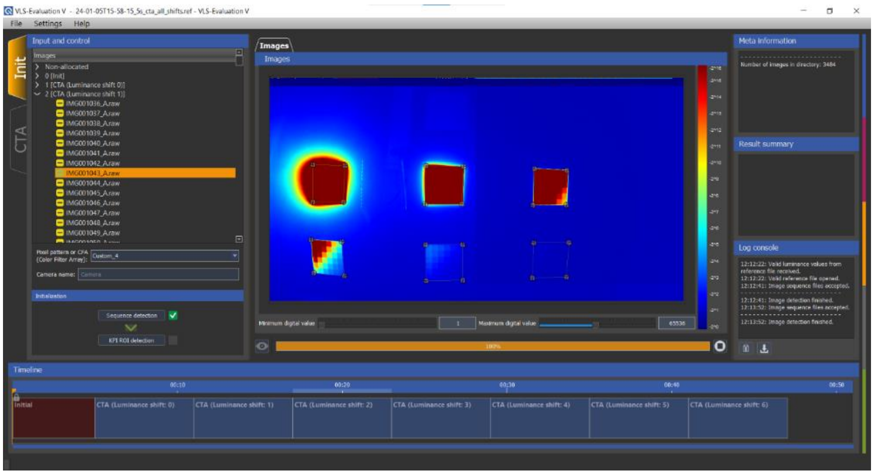


Figure 22 The VLS evaluation application

The VLS evaluation software aims to evaluate the following KPIs:

- CTA (Contrast Transfer Accuracy)
  - Spatial CTA measurements using VLS-Control (measurements with multiple luminances being recorded in one image)
  - Temporal CTA Measurements using a JSON interface (measurements with luminances in one image each)
- CSNR (Contrast Signal-to-Noise Ratio)
- CNR (Contrast to Noise Ratio)
- DR (Dynamic Range)
- MMP (Modulated light Mitigation Probability)

More details regarding these metrics can be found in the IEEE P2020 standard documentation. Please contact Image Engineering support for more information.

For each of these measurements, the camera recording is required in the form of several image files and a reference file of the VLS-Control software:

- **Image data:** The camera images must all be stored in a shared folder for each measurement. The formats TIFF, JPG, BMP, and binary Bayer image data up to 32-bit color resolution are currently supported. The Vegas test charts must be recognizable in the image data. If measurements were taken in automatic mode, the flashing sequences must also be recognizable before and after the measurement phases.

- **Reference file:** The VLS-Control software generates a reference file during the measurement, which is required for the evaluation. The reference file contains all metadata and measured values of the sequence playback needed for the assessment. Using the reference file belonging to the measured image data is essential for a correct evaluation.
- **Temporal CTA file:** As an alternative to VLS-Control based measurements, we also support the evaluation of a simple json mapping from image to luminance.

Import reference files and image data

To open a measurement taken with VLS-Control, you need to load the reference file and the recorded image sequence.

First, open the data input dialog via the "File..."->"Open reference file…" menu item.

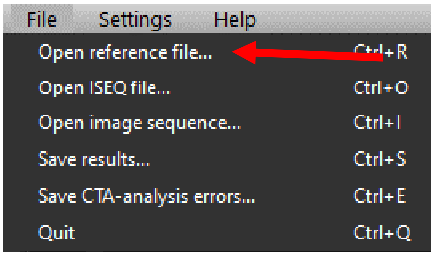


Figure 23 Option to read in the reference file

Use the input fields or the “Browse…” buttons to open the reference and image files. The software will preview the reference file’s data and the full image sequence.

By clicking on an image file, you can view it in the thumbnail below the list.

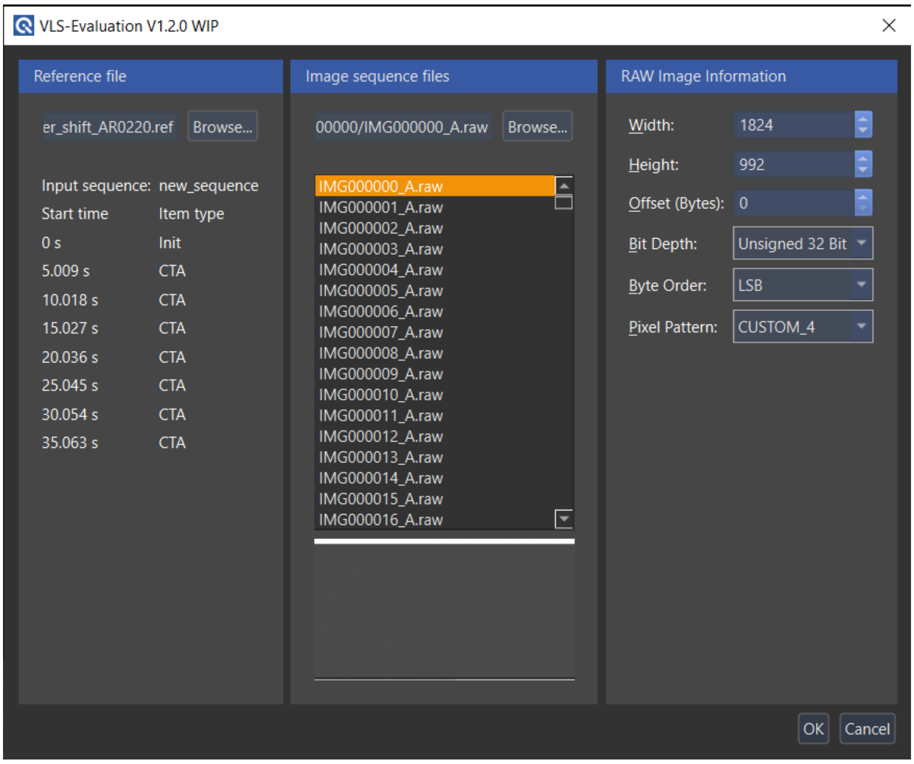


Figure 24 The data input dialog

RAW images

If the image sequence consists of RAW images, you must enter the corresponding information in the "RAW Image Information" section of the data input dialog.

This information consists of the following data:

- „Height", height of the image in pixels
- „Width", width of the image in pixels
- „Offset (Bytes)", size of the header/byte offset before start of image data in bytes
- „Bit Depth", bit depth of the image format, not necessarily the same of the bit depth of the contained data, possible values: „UNSIGNED_8", „UNSIGNED_16" or „UNSIGNED_32"
- „Byte Order", byte order of the raw data, possible values: „LSB" (least significant bit) or „MSB" (most significant bit)
- „Pixel Pattern", CFA Pattern, possible values: „MONOCHROME", „CUSTOM_4", „RGGB", „BGGR", „GRBG" or „GBRG", see further explanation in Chapter Pixel Pattern/Color Filter Array

Pixel Pattern/Color Filter Array

The Color Filter Array (CFA) of a sensor for multi-channel image data must be selected manually, as some KPIs require a separate measurement per channel. The CFA is a 2x2 pixel matrix starting in the image's upper left corner. Therefore, the upper left corner of the CFA always has an odd number of rows and columns:

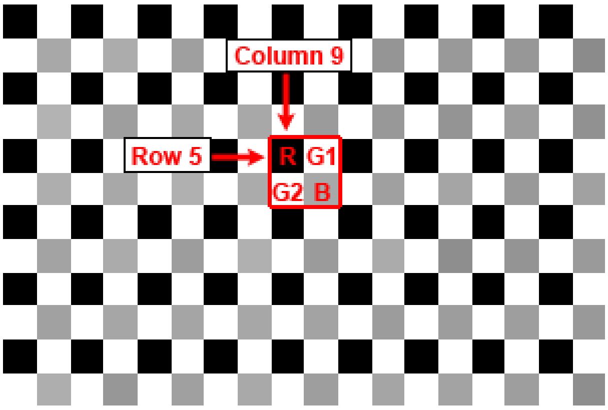


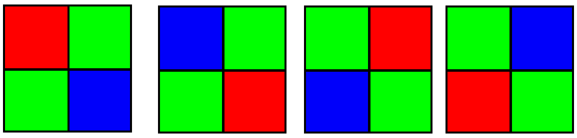
Figure 25 Example Bayer Pattern

The following options are available:

- *Custom_4*: No defined pattern; the color channels are displayed according to the following indexing:

Ch 1	Ch 2
Ch 3	Ch 4

- RGGB, BGGR, GRBG and GBRG: common CFAs



- *Monochrome*: for images without CFA

Image display

The image display can be seen in the center of the VLS evaluation software. Here, the image data can be viewed in more detail, and the ROIs can be positioned precisely for calculation.

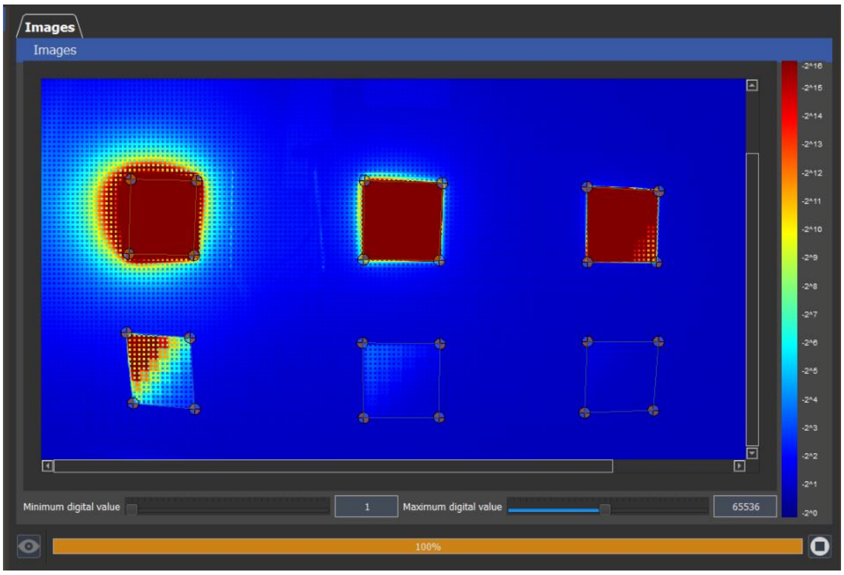


Figure 26 The image display and ROI selection

Left-click and move the mouse to navigate in the image—Double-click with the left mouse button to zoom the image back into the full view.

In false color mode, the photos are displayed with colors that depend on the color scale on the image's right side. The color range can be selected by changing the minimum and maximum digital values. Note that the gradation of the color scale is in powers of two. This setting allows simple gradation with a high dynamic range of the image.

Log console

The "Log console" panel shows messages about important events, actions, and errors in the software.

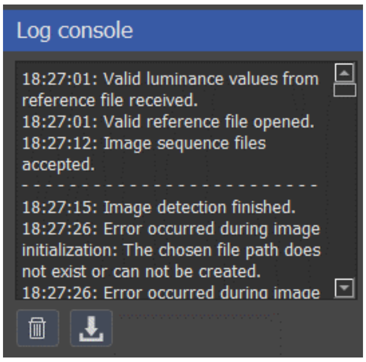


Figure 27 The "Log console" panel

Timeline

The sequence being played back is displayed in the timeline panel. If the sequence has been recognized correctly, a right-click on the sequence element highlights the corresponding images in the image list.

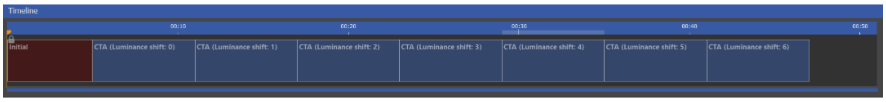


Figure 28 The "Timeline" panel

Measurement result display

There are tabs for displaying the measurement results for the various KPIs:

Figure 29 Example of the measurement result display

The result display supports the following control options:

- Zoom in/out via mouse wheel
- Zoom via rectangle with Shift + left-click
- Moving the view with the Ctrl key + left-click
- Reset the view by double-clicking the left mouse button.
- The mouse cursor always shows the values of the underlying measuring points
- Left-click to turn the cursor into a ruler to show distances.

KPI measurement

For measurements done with the VLS-Control Software, the following are required to calculate the KPIs:

- A file folder with the image data of the sequence
- The corresponding reference file

Requirements for the image data:

- The images must contain all VLS targets.
- The images must be numbered consecutively at the end. Avoid additional numbers in the file name, as this could affect the order in which the software imports them!
- The VLS targets must not move in the image during the sequence, as the detected ROIs are used in all subsequent images.
- At least four of the first images must contain the initial sequence; otherwise, the charts cannot be recognized automatically.
- Please check whether the frames entered in the individual steps are all valid. You can do this using the image display. There may be failures or artifacts from the camera that affect the results. It can also happen that part of the flashing sequence or the fading in of the light sources is recognizable. In the settings dialog, you can skip frames with the settings "Skip at start ... item" and "Skip at end ... item" settings.
- A sufficient number of images should be taken for the CTA step to improve the measurement quality. The CTA measurement collects the digital values for each patch in consecutive images and performs the CTA evaluation based on the distribution of these values.
- For CTA, the images should have a height of at least 1000px to provide sufficient data in the ROIs.

Settings

General

The options relating to the image display or general KPI settings can be changed in the general settings.

- *Maximum number of threads*:
  The software recognizes the number of processor cores and uses multithreading to distribute calculation processes. The value is set automatically, and it is recommended that the default value be used.
- *Color Map Type*:
  This option determines the *data display's color map (assignment of numerical value to color)*.
- *Image Display with false colors*:
  This option deactivates the color map and displays a black-and-white image.
- *Manual detection*:
  Sometimes, the automatic detection of the Vega charts fails. In these cases, manual detection can be carried out.
- *Export CTA additional results*: Exports the underlying probability distributions and the CTA measurement. This option increases the file size and duration of the export many times over.

CTA

The CTA measurement determines the probability of the device correctly transmitting a contrast. This probability is based on the pixels' value distributions (PDFs) corresponding to the brightness reference values. A number of parameters can be set for the CTA measurement:

- *Suppress PDFs below*: Prevents the use of PDFs with fewer values/support points than specified.
- *Whisker outlier factor:* Factor for determining outliers. It is used to detect hot/dead pixels. It is used together with the "Use whisker outlier detection" checkbox. The outliers are grayed out in the PDF display.
- *Number of randomized pixels:* The number of random pixel value pairs to be compared per pair of patches in the CTA chart. The default value is 50000 comparisons and should not usually be changed.
- *Confidence interval:* The confidence interval of the CTA measurement. The default value is 50%
- *Luminance contrast:* The contrast for which the CTA metric is calculated. Typical values are 6, 10, and 35%.
- *Luminance contrast tolerance:* The contrast range for which the CTA is calculated. The measured brightness values typically vary. This parameter is used to specify a tolerance range, e.g. 35% ± 2%.
- *Minimum ROI area:* Defines the minimum size of the region of interest per patch per chart. The measurement is aborted if at least one of the selected ROIs is smaller than this limit. The value should not be reduced, as this reduces the accuracy of the CTA measurement.
- *Required ROI numbers:* The minimum number of ROIs. There is one chart per Vega and 36 patches per chart. The default value is, therefore, 216 and should not be changed.
- *ROI to patch size ratio:* The size ratio of the ROI to the CTA patch. The default value is 0.8. Larger values increase the number of pixels but result in the inhomogeneous edges of the patches becoming part of the measurement. Lower values reduce the number of pixels and, therefore, the accuracy of the brightness distribution per patch.
- *Number of bins in PDF_K:* Number of bins for a more comprehensible display of the PDF_K curve.
- *Evaluation type:* The type of contrast calculation, officially CTA, should be performed with Weber or Michelson contrast. For special applications, the value difference of K_{Diff} is helpful.
    - K_{Diff} : PDF(K) = PDF(B) - PDF(A)
    - K_{Weber} : PDF(K) = [PDF(B) / PDF(A)] - 1.0
    - $K_{Michelson}$: PDF(K) = [PDF(B) - PDF(A)] / [PDF(B) + PDF(A)]

- *Skip at start of CTA Item:* Depending on the accuracy of the sequence detection, individual unswept frames may still be present at the start of the sequence element. This is to ensure that the light sources have been switched on. It makes sense to skip the first second of the recording (i.e., 30 frames at 30 FPS).
- *Skip at end of CTA Item:* Depending on the accuracy of the sequence recognition, the beginning of the flashing sequence may be displayed here and should be skipped.
- *Use Whisker outlier detection:* Activates detection of outliers in the pixel values. (Hot/Cold/Dead Pixel)
- *Ignore negative K:* If certain patches are brighter than they should appear due to unintentional reflections, the resulting negative contrast values can be ignored with this function.
- *Ignore the upper limit of the confidence interval:* Sets the upper limit of the confidence interval to infinity.
- *Reduce number of CTA Patch Pairs*: For highly resolved measurements (e.g. VLS-Control CTA Measurements with all luminance shifts) the calculation of CTA can take a long time. If only a partial result is sufficient for the use case, the amount of patch pairs to be calculated can be reduced. For this goal the measurement space is split up into a grid consisting of contrast bins and luminance bins. For each cell of this grid only a limited amount of patch pairs is analyzed. You can see the grid in Figure 30 Rasterization of measurement space.
    - *Limit pairs per cell*, the maximum amount of patch pairs per cell
    - *Luminance bins*: the number of luminance ranges
    - *Contrast bins*: the number of contrast ranges.

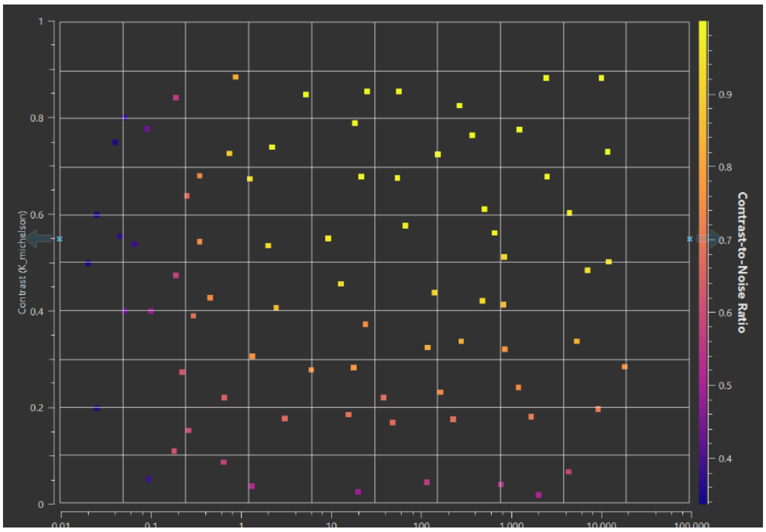


Figure 30 Rasterization of measurement space

Read the KPI documentation to gain a complete understanding of these parameters.

Click the reset button next to the parameters to reset them to the default values. If the values deviate from the standard, they are marked in red.

Advanced settings
The "Advanced settings" tab contains settings for the automatic detection algorithms, etc. The values should not be changed without contacting Image Engineering support. If the detection fails regularly, contact support.

Settings Import/Export
Using the buttons at the bottom of the dialog settings can be imported and exported in a .ini-File format.

Initialization step

The initialization step is automatic at the start of the sequence and is used to detect the targets. In the initialization step, all Vegas should be approximately equally bright. If this is not the case, repeat the absolute calibration. If this does not help, contact Image Engineering support.

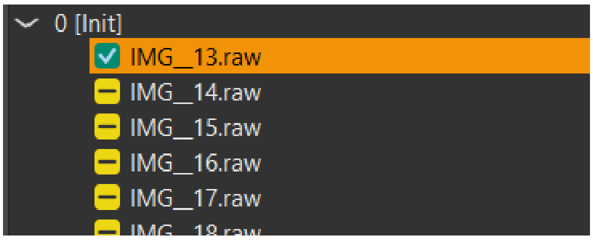


Figure 31 Images of the "Init" step for ROI detection

Figure 32 The timeline after reading in the sequence

Sequence detection

After opening the reference file and image sequence, as shown in Import reference files and image data, click the "Sequence detection" button to assign image data to the sequence elements automatically.

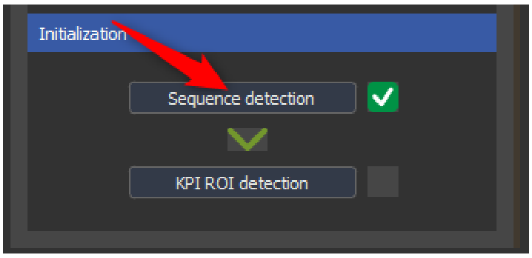


Figure 33 "Sequence detection" button in the "Initialization" panel

After running the automatic sequence detection, a dialog will show the detection result:

Figure 34 Successful sequence detection

In the dialog you can see the following:

- The average image brightness in digital values (white line plot)
- Green sections, showing which images are used for the evaluation of each sequence item.
- Orange sections, showing which images correspond to some sequence item but are skipped due to the sequence settings.

Due to the blinking before and after each sequence item being considerably brighter than the measurement illumination, you can use it as a marker for the start and end of each item.

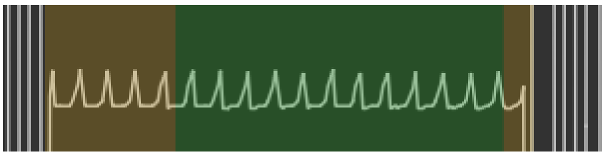


Figure 35 Close-up view of a successful detection, the first second is skipped for transients of the Vega light sources, the last few frames are skipped to not include any part of the blinking phase.

A successful detection is marked by skipping approximately the first second of the item to let the light source settle and ensure no blinking sequence frames are part of the green region.

Changing the “frames per second” value will rerun the automatic detection with the updated value.

In the worst case of a failed detection, you can use the sliders in the “Sequence item image ranges”-Box to adjust the ranges manually.

Figure 36 An example of a failed detection

After successful detection, the images are grouped according to the sequence elements in the image list in the "Init" tab.

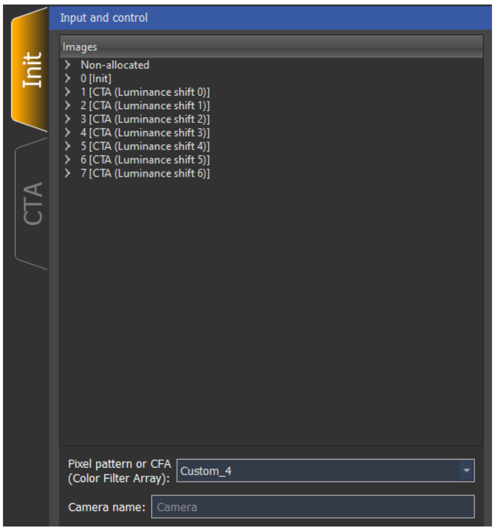


Figure 37 Init tab of the application

The sequence itself is displayed in the timeline.

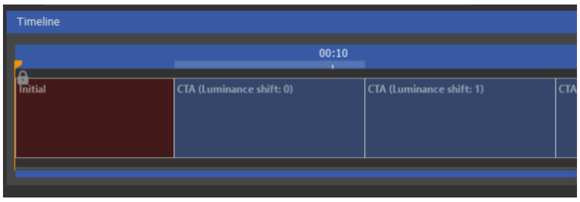


Figure 38 Sequence in the timeline

The respective image is displayed by clicking on the file name in the image list, and you can check whether the assignment was successful.

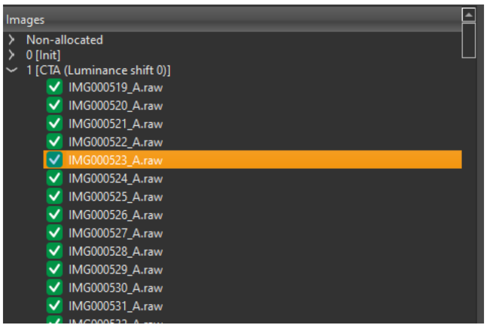


Figure 39 Successful sequence detection

After successful sequence detection, you can continue the evaluation with the KPI-ROI selection.

KPI ROI Selection

CTA/MMP

By default, the application attempts to recognize the ROIs automatically. The success rate depends heavily on the lighting and the image's noise.

If the ROIs are not positioned correctly, they can be adjusted manually. The correct selection should look similar to the following pictures:

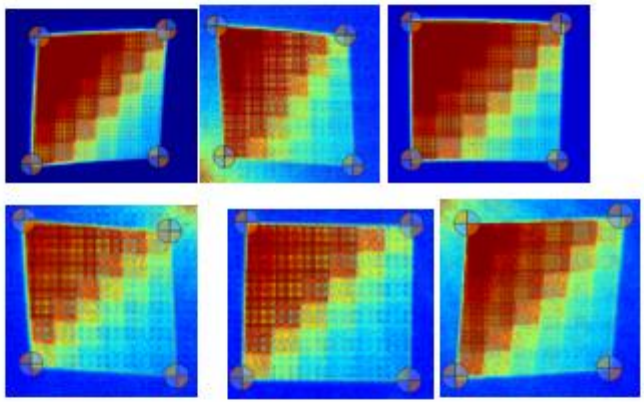


Figure 40 Example of an ROI selection

After positioning the ROIs, their coordinates are saved as a file in the image folder. This feature means that ROI detection must only be done once per measurement. If several measurements have been carried out with the same setup, you can save the ROI file in the folder to shorten this step.

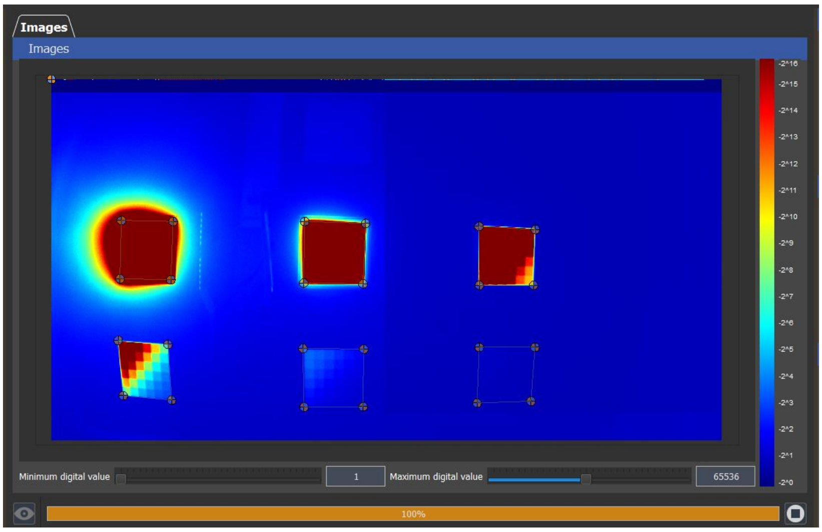


Figure 41 ROI selection

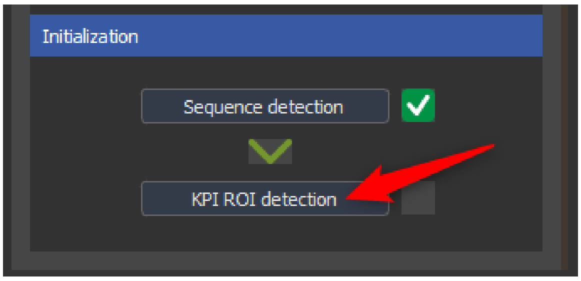


Figure 42 "KPI ROI detection" button in the "Initialization" panel

After selecting the chart ROIs, click the "KPI ROI detection" button. This selection will automatically generate the patch ROIs. The patch ROIs should be centered on the patches. If the recording is heavily distorted or the light sources are positioned at an angle, adjust them accordingly.

The actual analysis can now be carried out. Start the image processing step with the "CTA image processing" button. The following steps work analogously for the calculation of MMP.

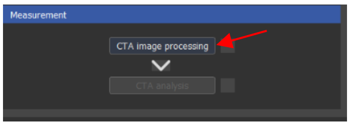


Figure 43 "CTA image processing" button in the "Measurement" panel

This step reads the ROI pixels from the images and converts them into a usable format for further processing. The process may take a few minutes. This step must be repeated if the ROIs are moved after the calculation.

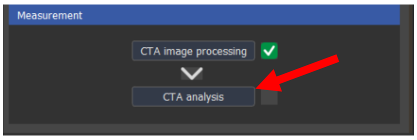


Figure 44 "CTA analysis" button in the "Measurement" panel

After image processing, the analysis can be started by clicking the "CTA analysis" button.

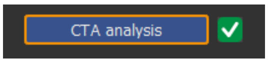


Figure 45 "CTA analysis" button after a successful analysis

You can change the analysis settings after the export to perform multiple analyses. The image processing step does not have to be repeated. After the analysis, the results are displayed in the "Results" tab.

Import Temporal CTA data

Compared to the spatial CTA measurement (performed with VLS-Control), a temporal CTA measurement is done by capturing one image per luminance step.

To allow flexible CTA, measurements VLS-Evaluation supports the evaluation of a json based mapping to evaluate temporal CTA measurements. To differentiate the data from other file formats, we use the „.tcta“ file extension to mark its content. The temporal CTA measurement is assumed to have a single region of interest across all images.

To open a temporal CTA measurement, use the „File…“->„Open temporal CTA File…“ option in the menu. The calculation works the same way as spatial CTA, except the sequence and ROI detection steps can be skipped (see Chapter KPI ROI Selection → CTA/MMP).

Temporal CTA measurements currently do not support the error estimate export.

JSON-Format
This is a shortened example of a .tcta file:


```
{
  "luminance_multiplier": 1.0,
  "raw_image_info": {
    "height": 2201,
    "offset_bytes": 38560,
    "width": 3658,
    "depth": "UNSIGNED_16",
    "byte_order": "LSB",
    "pattern": "CUSTOM_4"
  },
  "roi": {
    "top_left_x": 1779,
    "top_left_y": 1000,
    "width": 100,
    "height": 100
  },
  "items": [
    {
      "filename": "img_0.raw",
      "luminance": 0.01
    },
    {
      "filename": "img_B.raw",
      "luminance": 0.02
    },
    {
      "filename": "more items and luminances...",
      "luminance": 0.03
    }
    ]
}
```


The json format is minimalistic and consists of the following values:

- „luminance_multiplier“, a scalar multiplier for all luminance values.
- „raw_image_info“, raw image information (see RAW images)
    - „height“, height of the image in pixels

  - „width“, width of the image in pixels
  - „offsetBytes“, size of the header/byte offset before start of image data
  - „depth“, bit depth of the image, possible values: „UNSIGNED_8“, „UNSIGNED_16“ or „UNSIGNED_32“
  - „byteOrder“, byte order of the raw data, possible values: „LSB“ (least significant bit) or „MSB“ (most significant bit)
  - „pattern“, CFA Pattern, possible values: „MONOCHROME“, „CUSTOM_4“, „RGGB“, „BGGR“, „GRBG“ or „GBRG“
- „roi“, the region of interest within the image data
  - „top_left_x“, x position of the ROI’s top left corner
  - „top_left_y“, y position of the ROI’s top left corner
  - „width“, width of the ROI in pixels
  - „height“, height of the ROI in pixels
- „items“, the mapping of image data to luminances
  - „filename“, the filepath, either absolute or relative to th e .tcta file
  - „luminance“, the luminance value (in Cd/m²)

Command line interface
Due to the temporal CTA evaluation not requiring lots of user interaction, it can be launched as a command line tool.

To do this you require:

- The .tcta File as previously described.
- The corresponding image files.
- A „.ini“ settings file, this can be exported using the options dialog. Make sure to include CTA in the export settings.

To start the command line evaluation use the following syntax:

```
VLS-Evaluation.exe -i temporal_cta.tcta -c cta_settings.ini -o output.xml
```

The results are then saved in the output.xml file.

The command line utility also shows its documentation when using the „-h“ flag as in „VLS-Evaluation.exe -h“.

The usual restrictions of a command line utility are in action, so the executable directory needs to be added to your „Path“ environment variable, or reached via relative or absolute path. Any file paths containing spaces need to be escaped e.g. using quotes around the path in the windows command line.

Contrast metric results

If a CTA step exists in the sequence, there is an associated list of the measured brightness values:

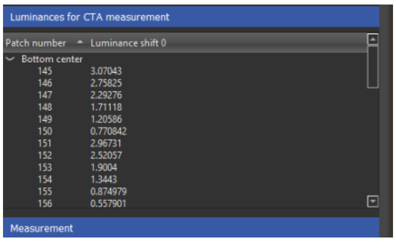


Figure 46 Brightness values for the CTA measurement

PDF plot

Figure 47 The PDF plot

The PDF plot shows the value distributions of two Vega patches and the resulting distribution of contrast values. The red line marks the mean value of the contrast measurements, and the green lines mark the upper and lower tolerance limits.

CTA plot

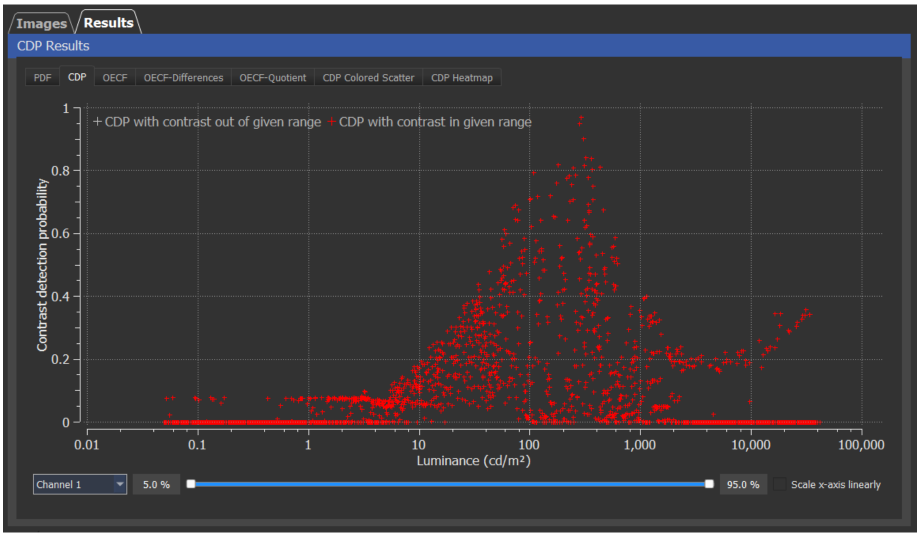


Figure 48 CTA plot (formerly CDP)

The CTA plot shows the individual CTA measurements per luminance. The slider can be used to limit the relevant contrast values.

OECF plot

Figure 49 OECF plot

The OECF plot shows the OECF, i.e., the average assignment of luminances to digital values, for a single channel.

OECF difference plot

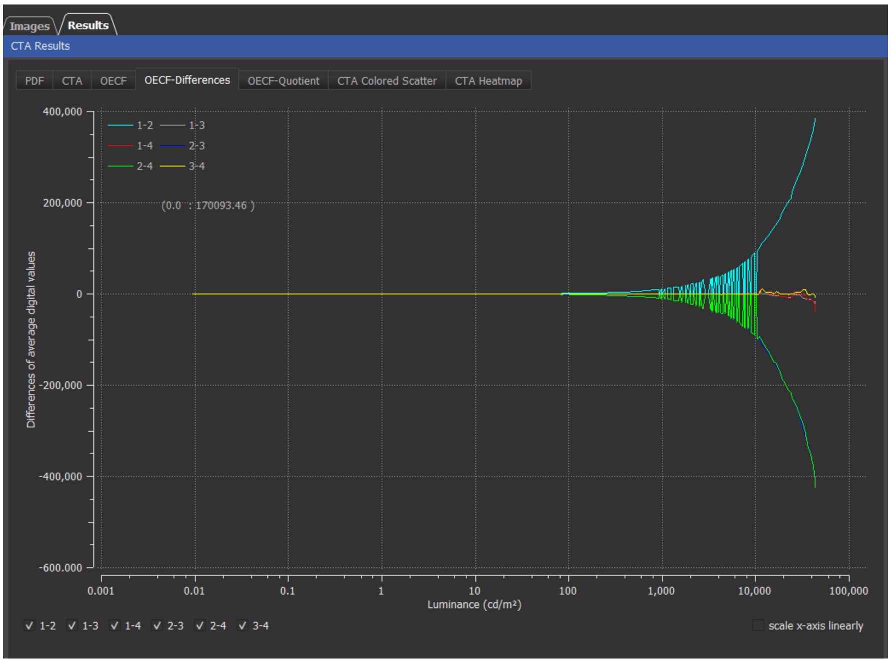


Figure 50 OECF difference plot

The OECF difference plot shows the absolute differences between the OECF curves per channel.

OECF quotient plot

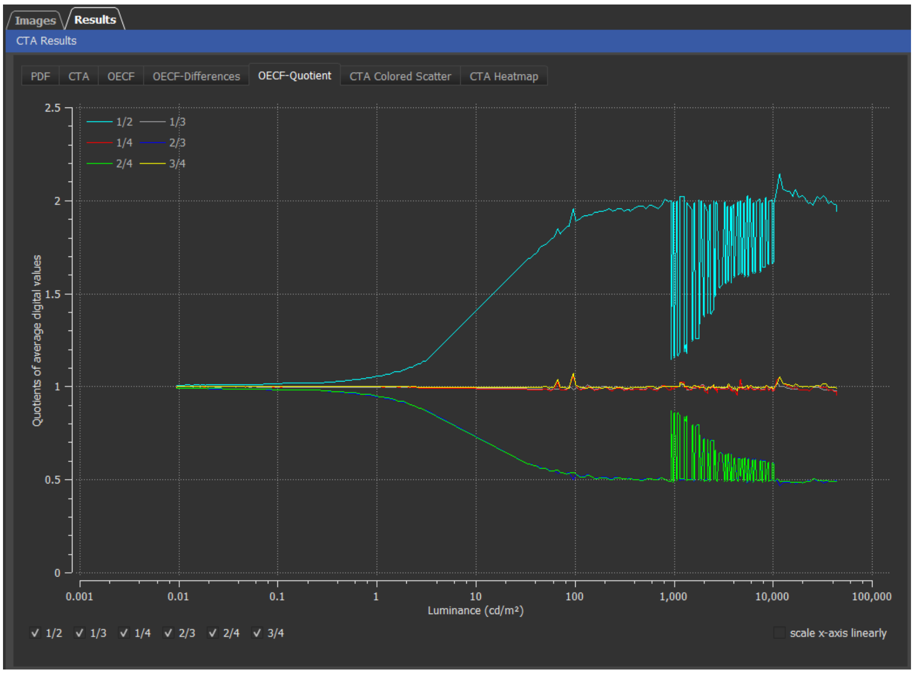


Figure 51 OECF quotient plot

The OECF quotient plot shows the relative ratios of the OECFs per channel.

CTA-Colored-Scatter-Plot

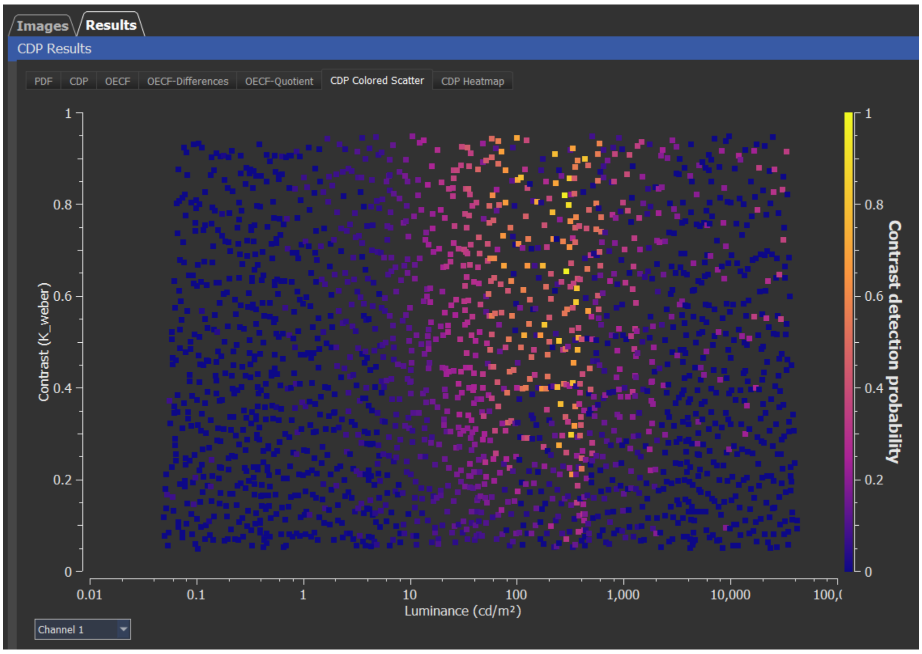


Figure 52 CTA-Colored-Scatter-Plot

The CTA scatter plot shows all CTA measured values along the contrast and brightness axes. The color value encodes the CTA value according to the legend.

CTA heatmap plot

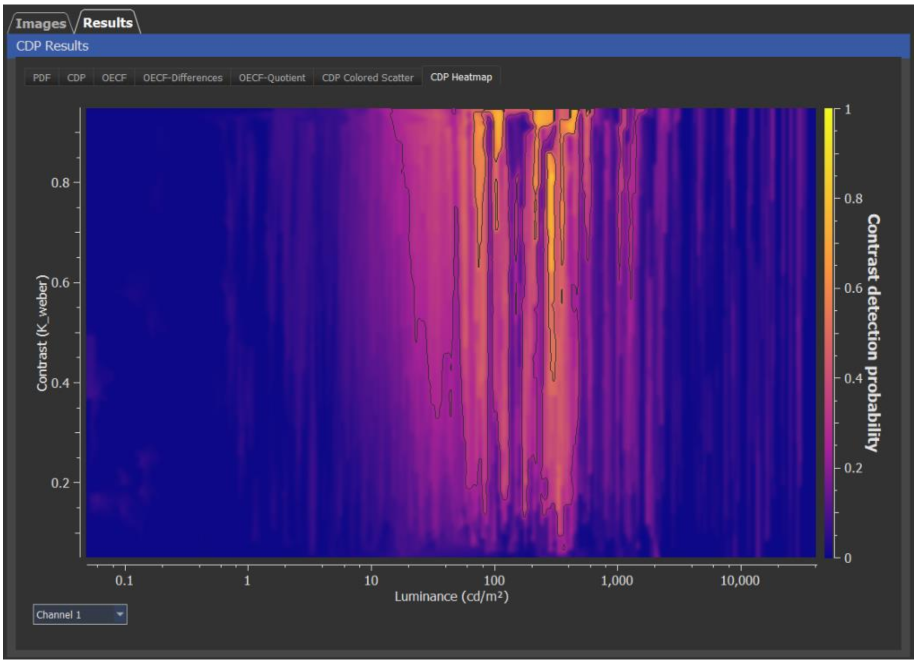


Figure 53 CTA heatmap plot

The CTA heatmap plot shows an interpolation of the CTA scatter plot

CSNR and CNR Plots
There are plots for the metric CSNR, which are rendered in relation to the same parameters as CTA.

The CNR value plots refer to the same luminances as the CTA Plots, but their contrast value is the simple luminance contrast of the patches A:B.

There are additional plots for the CNR metric calibrated to the 2:1 contrast according to IEEE P2020 specifications.

Dynamic Range
The Calibrated CNR plot has an additional threshold control that allows dynamic range calculation per IEEE P2020.

Flicker metric results

MMP
After successful image processing and MMP analysis, the results can be seen in the following plots.

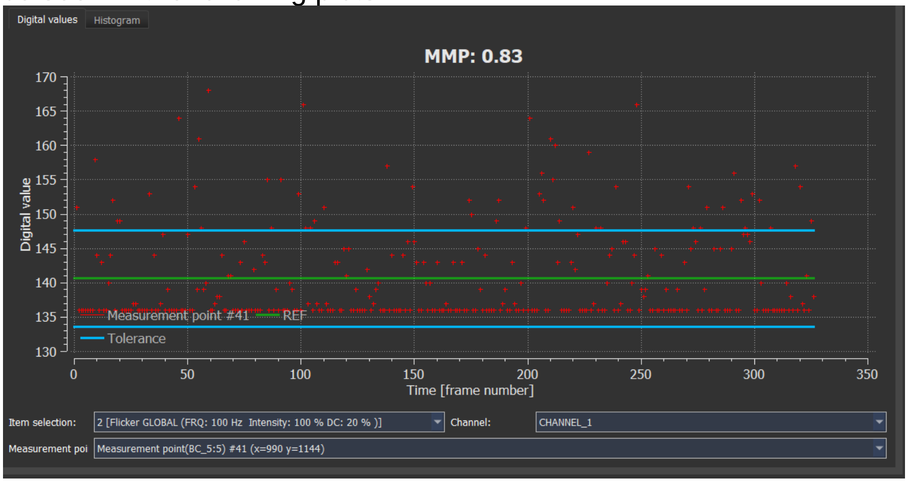


Figure 54 MMP Digital Values Plot

This plot plots the digital values vs. the frame number for a specific Vega patch in a particular item/step. The green line represents the average DV, and the blue lines are the selected tolerance. If all DVs are in the tolerance, MMP equals 1. All results are separately displayed for any color channel of the image.

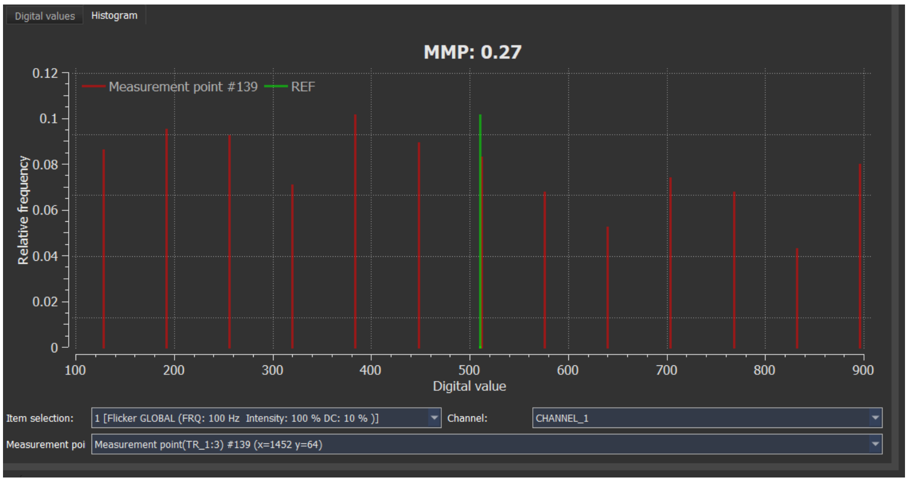


Figure 55 MMP Histogram

This plot shows the distribution of the DVs. The green line represents the average DV, and the red lines are the frequency of the actual DVs in bins. The closer the red lines are to the green line, the better the MMP.

Results export

All results are written as an XML file. To do this, use "File->Save results..." in the main menu. If the value distributions are also to be exported, use the "Export additional results" option in the settings dialog.

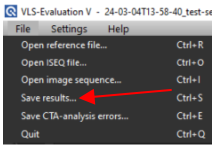


Figure 56 "Save Results..." option

3.4 3rd Party components

VLS uses the following OpenSource components:

libusb (www.libusb.org) is licensed under GNU Lesser General Public License version 2.1 (www.gnu.org/licenses/old-licenses/lgpl-2.1.html).
Qt (www.qt.io) is licensed under GNU Lesser General Public License version 3.0 (www.gnu.org/licenses/lgpl-3.0).

QsLog Copyright 2014, Razvan Petru
(https://github.com/victronenergy/QsLog)

QwtPlot (*https://qwt.sourceforge.io/*), Uwe Rathmann, Josef Wilgen, is licensed under GNU Lesser General Public License version 2.1 (www.gnu.org/licenses/old-licenses/lgpl-2.1.html).

4 Appendix

4.1 Service addresses

E-mail: support@image-engineering.de

5 Glossary

Chart

In the context of these instructions, "chart" describes the patterned foils positioned on the Vega light source.

CNR

Abbreviation for “Contrast to Noise Ratio”

CSNR

Abbreviation for "Contrast Signal-to-Noise Ratio"

CTA

Abbreviation for "Contrast Transfer Accuracy". A metric that describes how well an optical system can reproduce a contrast at a given brightness. Can be measured spatially by measuring multiple luminances in one image, or temporally by measuring one luminance per image.

Calibration

In the context of this application, it describes the calibration process of either the Vega light sources or the overlying charts to generate the reference values required for the measurement based on the device's internal measurements.

DR

Abbreviation for “Dynamic Range”.

KPI

The abbreviation for "Key Performance Indicator" that describes the various metrics this software covers (CTA, CSNR, etc.).

MMP

The abbreviation for "modulated light mitigation probability" describes a sensor's ability to avoid "flicker."

OECF

The abbreviation for "opto-electronic conversion function" describes the correspondence between incoming brightness and the resulting pixel value for an image sensor.

Patch

Single field of the 6 x 6 grid of the TE294 charts

RAW

Term for image files that store brightness values per pixel "raw," i.e., without lossy compression schemes or projection onto a color space.

Reference file

Refers to a file created by the VLS-Control software that includes information on the measurement performed. It contains measured values of the light sources and the underlying sequence.

Sequence

Refers to a time-defined sequence of several steps (sequence elements) for measuring the KPIs. It is displayed in the various applications in the timeline.

Target

Refers to the target of the image measurement. In the context of VLS, the TE294 chart placed on the Vega light source is the target.

TE294 (Chart)

A particular type of chart for measuring contrast-based KPIs that is divided into 6 x 6 fields of different brightness, with a pairwise ratio of approximately 1:1.07 in brightness. Thus, the brightness ratio from the brightest to the darkest field is 1:10.

Timeline

The timeline in which the sequence is displayed. It is divided into its sequence elements.

Vega

The product name for the light sources used to measure various metrics.

VLS

VLS is the name of the product and stands for Versatile Light System. Divided into the components VLS-Control and VLS-Evaluation