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# camSPECS

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Quick Start Guide

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**Image Engineering GmbH & Co. KG** · Im Gleisdreieck 5 · 50169 Kerpen-Horrem · Germany

T +49 2234 2273 99 99 1-0 · F +49 2234 2273 99 99 1-10 · [www.image-engineering.com](http://www.image-engineering.com)



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# 1 INTRODUCTION

Important information: Read the manual carefully before using the device.

Inappropriate utilization may cause damages to the device.

Keep these instructions in a safe place and pass them to any future user.

## 1.1 Intended use

camSPECS consists of an illuminating hardware device and a software for evaluating the spectral sensitivity of camera systems. The included spectrometer EX1 is used for periodic on-site calibration.

The camSPECS software is used for the measurement of the spectral sensitivity by means of captures of the filter plate taken with your camera system.

- Only suitable for indoor use.
- Place your system in a dry and constant tempered environment without any interfering light. Avoid high air humidity.

## 1.2 General safety information

The backside of the housing of camSPECS gets hot during operation.

- **Do not** cover the fan discharge ducts on the right and back side of the device.
- **Place** the back side of the device with **suitable distance to walls**.
- **Do not** open the top sliding port of the housing during operation for bulb exchange.
- **Do not** open the device when connected to the power supply.

# 2 GETTING STARTED

- Remove the packaging material.
- The plug for the power supply and the main switch are located at the back side of the box. Connect camSPECS with a power socket and switch it on and let it run for a couple of minutes until it reaches a stable temperature.
- First install the latest *Matlab Component Runtime* required for camSPECS. Execute the MCR installer (32 or 64 bit) and follow the instructions. This will install the *Matlab Component Runtime* on your system, if necessary.
- Then start *camspecs\_Vx.x.x\_win64.exe* or *camspecs\_Vx.x.x\_win32.exe* depending on your Windows operating system to install software. During the installation process you are asked to select the spectrometer component to install. If you have a spectrometer for calibration, select this option.

# 3 WORKFLOW

The general workflow of spectral response measurement and evaluation is described briefly.

## 3.1.1 Spectral sensitivity (camSPECS) module

- Start the camSPECS software and switch to module *Spectral sensitivity (camSPECS)*.



- Check the advanced settings menu to adjust the default values as needed.
- Add the initial calibration file delivered on the CD in the settings panel with the “+”-button. More files can be added or removed from the menu using the corresponding buttons (“+”, “-“). Calibration files created during calibration process with the software are automatically added to this menu.
- Update all other settings as needed and add an optional dark image.
- Select and add images with the '+' button.
- Click the *Start* button.
- Check the result of the automatic detection and confirm by double clicking on the image outside the displayed Regions Of Interest (ROI). The rectangles may be rearranged here if necessary.
- The result of the measurement is displayed and a text file with the name of the image is saved in the same directory as the images.
- For documentation purposes the spectral curves can be saved as an image file.

### 3.1.2 Spectral sensitivity (iQ-LED) module

- Start the camSPECS software and switch to module *Spectral sensitivity (iQ-LED)*.
- Select the desired *Spectral Sensitivity Database*.
- Select the *Dark frame*, if desired.
- Select the *Spectra* that were presented to the camera and were saved from the separate iQ-LED application software.
- Select the *Images* that were captured by the camera for each of the *Spectra*.
- Click the *Start* button.
- The computed spectral sensitivities are displayed and a text file is saved.

### 3.1.3 Validation module

- Take a picture of a ColorChecker (24 patches) or ColorChecker SG (140 patches) chart that was illuminated by a light source whose spectral distribution is included in the software (D50, D55, D65, A, C). Additional spectral distribution files can be added to camSPECS.
- The picture shall have uncompressed RGB or raw data (e.g. TIFF format).
- Select the *Validation* module and choose a spectral sensitivity measurement. The previous spectral measurement, if available, is shown in the highlighted field.
- Select the light source and reflectance data from the drop-down menus corresponding to the selected ColorChecker.
- Select the ColorChecker image.
- Select optionally a dark image for correction.
- Click the *Start* button and draw a rectangle around the patches in the displayed image.
- Double click on the image and check the positions of the ROIs in the next step. Their positions may be corrected by dragging and dropping them with the mouse before clicking on the image outside the ROIs to continue.
- The graph displays the measured RGB values for each patch plotted against the predicted values in normalized values (from 0...1).
- For documentation purposes the graph can be saved as an image file.

### 3.1.4 Color Transforms module

- Select the *Camera Spectral Sensitivities* file just created in one of the *Spectral Sensitivity* modules.



- Select the *Transform Type*, *Reference Illuminant*, and *Profile Type*.
- Select the *Training data* for which the transform will be optimized.
- Select the *Test data* on which the transform will be evaluated.
- Click *Start* to calculate the color transform.
- By default, the transform is applied to the *Test data* and a split view of each color and the color difference is shown in the evaluation panel.
- *Export* the ICC profile and matrices, if desired.

### 3.1.5 ICC profile evaluation module

- Load a raw camera image.
- Select a profile that was saved from the *CCM / ICC profile creation* module.
- The color managed image will be shown for viewing on an sRGB-calibrated display.
- Export the color managed image, if desired.

## 4 OPERATING INSTRUCTIONS

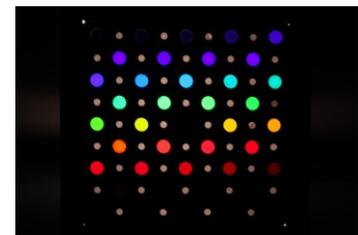
### 4.1 Camera settings

Set the camera to manual exposure mode, if available. To get best results the camera shall be able to save pictures as linear raw files.

Exposure program	Manual
Aperture	No default value
ISO Speed	Lowest value (e.g.100)
Auto focus	Off
File type	RAW

#### 4.1.1 Camera position and lenses used

Place the camera in front of the filter plate. The principal axis of the lens must be aligned perpendicular to the center of the filter plate. Adjust the distance between the lens and the filter plate such that the filter plate occupies approximately two-thirds of the field of view of the camera, centered. Avoid using wide-angle lenses, since there is a slight angle dependence of the radiance power and the peak wavelength of the interference filters. Using lenses with higher focal distances ensures a minimum viewing angle. Viewing angles below  $15^\circ$  do not cause noticeable impacts on the resulting spectral responses.



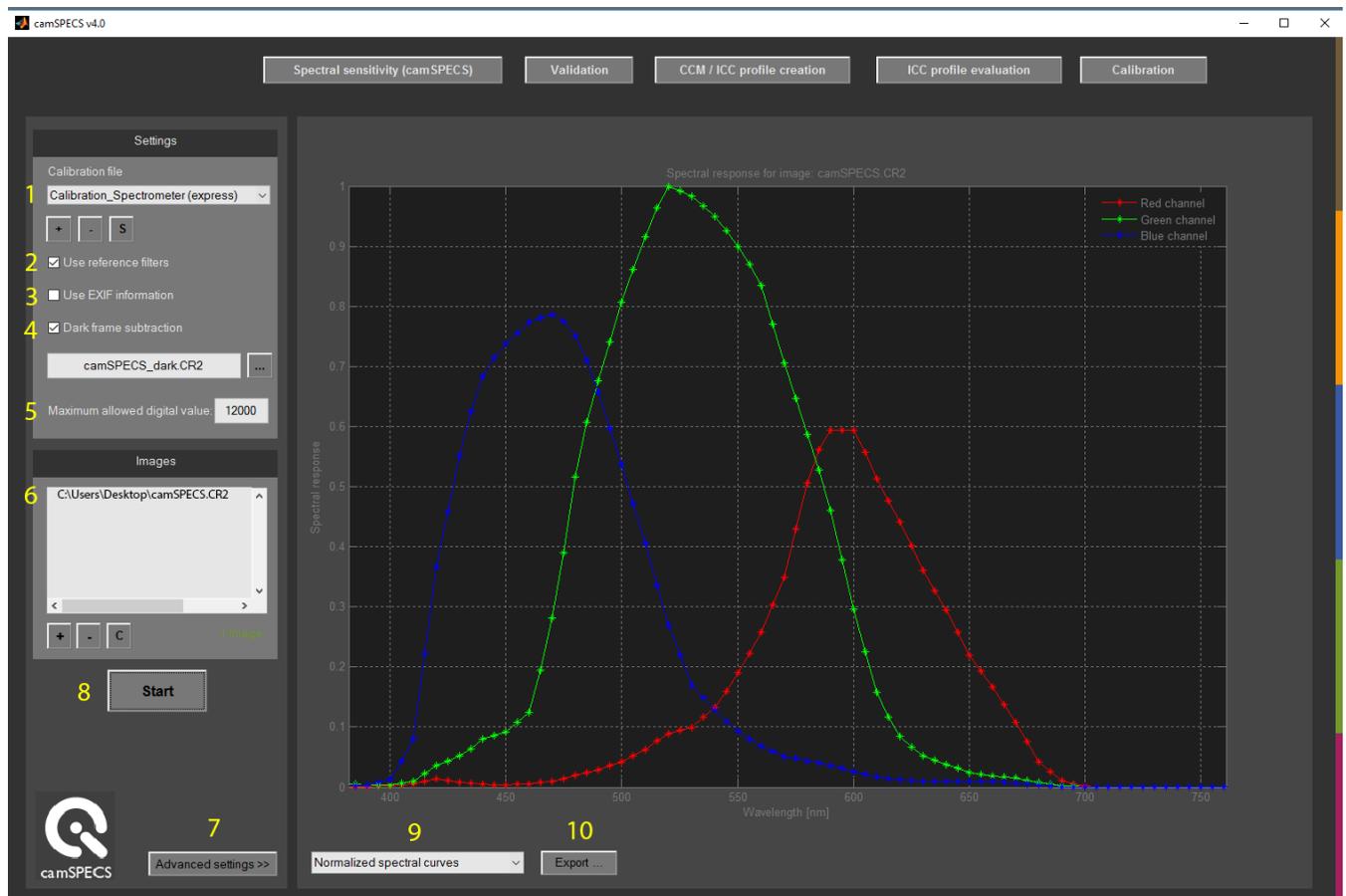
**Note:** Ensure that the filters are the only light sources that are captured by the camera. To avoid stray light or other light hitting the camera sensor the pictures should be taken in a dark room or the space between camera and the camSPECS device should be shielded.



#### 4.1.2 Exposure

Set camera exposure such that the maximum recorded value of the camera capture of the filter plate is approximately 75% of the valid encoding range. For instance, if the available encoding range is 16 bits per channel and the valid encoding range of the image data is 12 bits per channel, set the exposure so that the maximum value of the filter plate that is recorded is approximately 3000. To get correct results the image of the filters must not be overexposed. Take a picture with reasonable exposure settings (typically  $f = 5.6$ ,  $t = 1/2s$ , ISO 100, depending on camera and lens) in RAW mode (with Bayer pattern). Check the RAW image for the highest recorded value in all RGB channels using a RAW image viewer or converter (i.e. ddraw).

### 4.2 Spectral sensitivity (camSPECS) Module



1. Select the calibration file for your camSPECS device. With the '+' and '-' buttons calibration files can be added and removed from the list. Calibration files can be saved to a specified location with the 'S' button.
2. Use the reference channels (neutral density filters) to correct for exposure differences and inhomogeneities produced by the capturing camera system.
3. Use EXIF data for correction of different exposure settings. This is necessary when the automatic

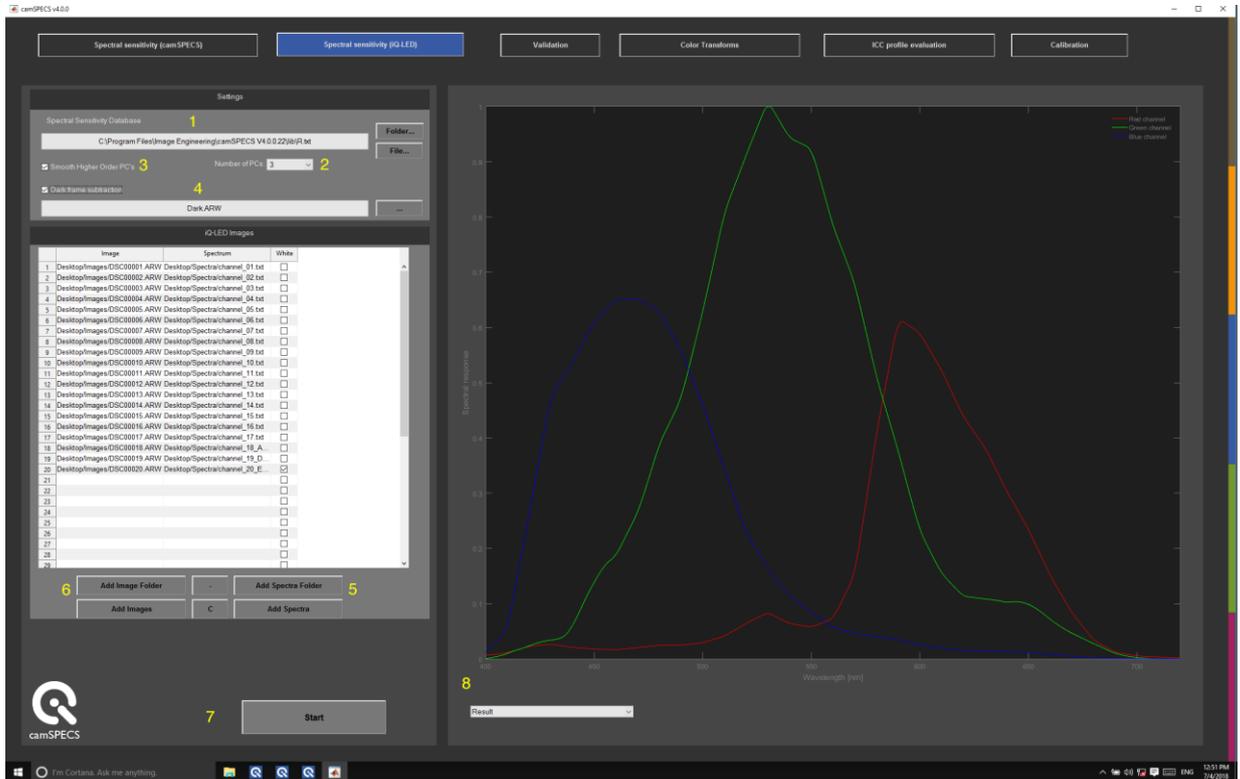


exposure control of the camera is used. This only applies to the camSPECS hardware with the sequential capturing mode ("Multi-shot").

4. Apply dark frame subtraction. Supported image types are: TIFF, PGM, BMP, PNG, PPM and raw files. Take an image with the same camera exposure settings as used for the camSPECS images. It will be subtracted from each image in the processing list. This option is used to subtract the offset value, inherent in all images, that has its origin in the dark current of the sensor. This offset value has a negative impact on the spectral measurement.
5. Set the maximum allowed digital value in accordance with the *Exposure* guidelines given above. If this value is exceeded in an image, an error message is displayed.
6. Add image(s) to processing list. Supported image types are: TIFF, PGM, BMP, PNG, PPM and raw files (The term "raw file" means files that are created by a digital camera in "RAW-Mode" and are readable by the software *dcraw*. This does not include raw files that do not follow any image file format. You should convert these files to 16-bit Tiff images first.). Depending on the selected calibration file (see item 1) you can choose one or more images that must contain the filter arrangement of camSPECS device. With the '+', '-' and 'C' buttons you can add images, remove one selected image or clear the whole list. After the measurement the spectral curve of the first image in the list is displayed. By clicking on the other images in the list the corresponding results are displayed.
7. Check the advanced settings.
8. Start the processing procedure. The filters in the images are detected automatically. After the detection process a confirm dialog is shown where the ROIs for each filter can be manually repositioned if necessary. By double-clicking on the background, the processing starts. The resulting spectral curves are displayed and saved to a plain text (.txt) and an XML file in the same directory as the original image directory. For the camSPECS version a tile image is saved to the same directory as the origin of the images directory assembled from the single images. Check this image for correct positions of the ROIs or all filters.  
In some cases, the filters of camSPECS images may not be detected automatically. In this case you are guided by semi-automatic filter detection with some controllers which restrict a couple of constraints for correct detection of the filters.
9. When the measurement is done you can switch between raw and normalized RGB spectral curves data.
10. Export the spectral curves to an image (JPEG, PNG, TIFF, BMP, GIF) for documentation purposes.



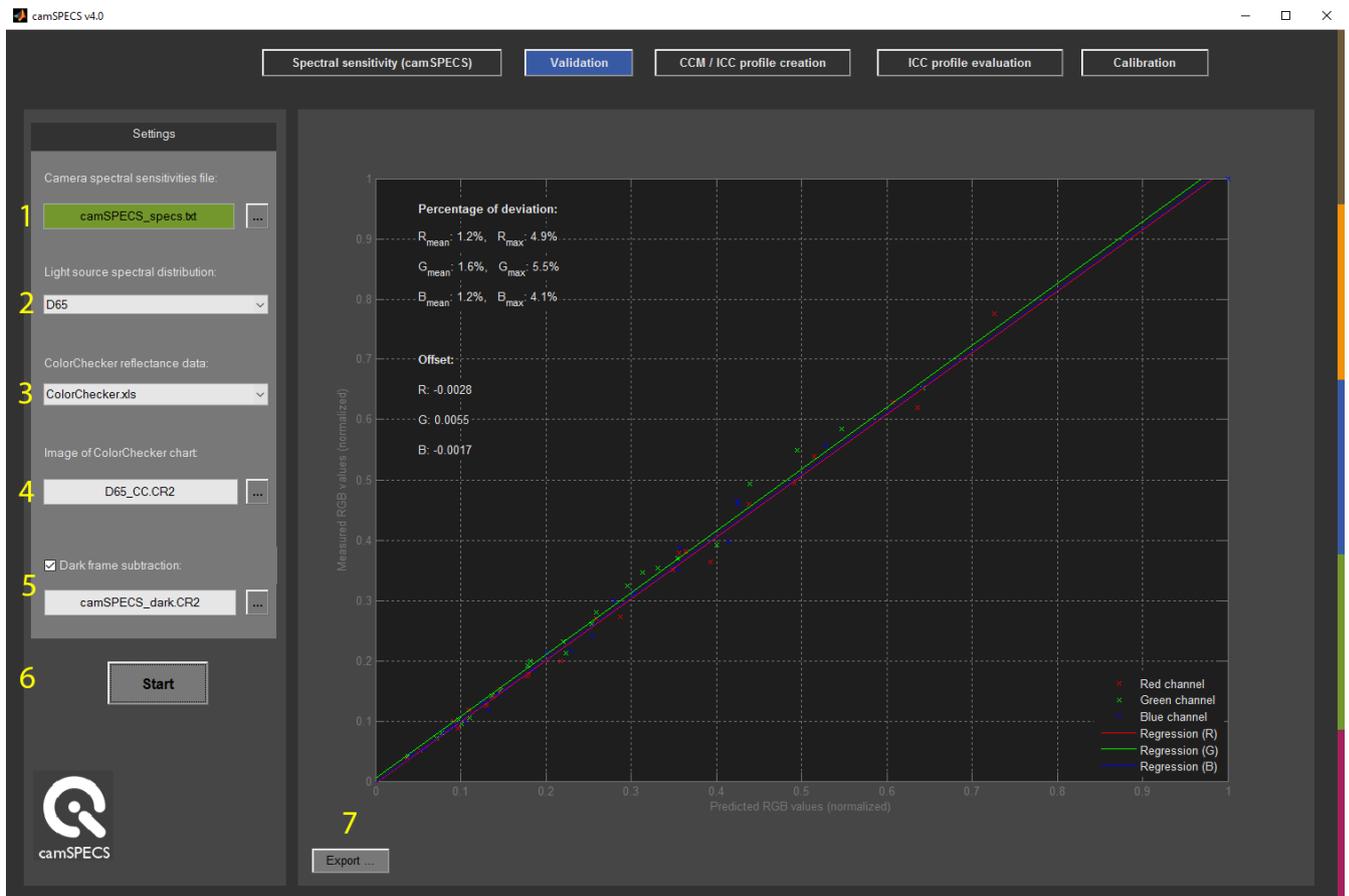
### 4.3 Spectral sensitivity (iQ-LED) Module



1. Select the relevant reference *Spectral Sensitivity Database*.
2. Select the *Number of PCs*;, the number of principal components extracted from the reference spectral sensitivity database to be used for computing the spectral sensitivity of the test camera.
3. Check *Smooth Higher Order PC's* to regularize higher-order principal components to reduce noise artifacts, if present.
4. Check *Dark Frame Subtraction ...* to select a dark capture taken with the camera with the lens cap on or other means to ensure no light reaches the image
5. *Add Spectra Folder* to select the folder containing the spectral power distribution files for the desired individual LEDs that were previously saved using the “Export” feature in the separate iQ-LED software.
6. *Add Image Folder* to select the folder containing the image capture files of each of the spectra specified in item 5 above.
7. Press *Start* to compute the spectral sensitivities of the test camera.
8. The *Results* panel shows the computed spectral sensitivities for the test camera.



## 4.4 Validation module



1. Select a spectral response file (.txt) with values interpolated to 5 nm (see advanced settings), that was created by camSPECS.
2. Select a spectral distribution for the light source used for the illumination of the ColorChecker test chart. Individual light sources may be used here. To create an individual light source file, intensity values for wavelengths between 380 and 780 nm in 5 nm steps are needed. Put this data into a text file with the wavelength values in the first column and the intensity values in the second column. Columns must be separated with a tabulator. The files in the /calibration\_files/lightsource directory of the camSPECS program folder may be used as a template. Format your file corresponding to these files and copy it to this folder then restart camSPECS.
3. Select ColorChecker reflectance data. The data used contains the spectral distribution between 380 nm and 730 nm in 5-nm increments.
4. Select a RGB image file of a ColorChecker test chart (ColorChecker with 24 patches or Color Checker SG with 140 patches). The image must be a raw image file. Do not use compressed image formats like JPEG or other output-referred encodings since source colors have been rendered.



5. Select optionally a dark image for subtracting from the ColorChecker image. The size of this image and the ColorChecker image must be the same.
6. After clicking the *Start* button the selected ColorChecker image is opened and displayed. Select the chart by drawing a rectangle around the patches from upper left to lower right and double click on the rectangle. The ROIs for each patch are displayed in the next step and can be rearranged manually. Double click outside ROIs to continue.
7. Export the validation graph to an image (JPEG, PNG, TIFF, BMP, GIF) for documentation purposes.

## 4.5 Color Transforms Module

The screenshot shows the camSPECS v4.0.0 software interface. The main window is titled 'camSPECS v4.0.0' and has a menu bar with 'Spectral sensitivity (camSPECS)', 'Spectral sensitivity (IQ-LED)', 'Validation', 'Color Transforms', 'ICC profile evaluation', and 'Calibration'. The 'Color Transforms' module is active, showing a 'Delta E' color comparison chart. The chart is a 4x6 grid of color patches with Delta E values. The settings panel on the left has numbered buttons 1 through 7. The bottom of the interface has a 'Start' button (8) and an 'Export...' button (11).

	A	B	C	D	E	F
1	0.1	1.9	0.2	0.3	0.2	1.8
2	0.5	0.7	0.7	0.2	1.1	0.4
3	0.6	0.9	1.2	1.2	0.8	0.9
4	0.7	0.3	0.1	0.0	0.0	0.0

1. Select a *Camera Spectral Sensitivites* file that was created by camSPECS.
2. Select the desired *Transform Type* from those available.
3. Select the desired *Reference illuminant* spectral distribution file for the light source of the scene adopted white point.
4. Select the desired *Profile Type* for which the transform will be created.
5. Select reflectance *Training data*. The resulting camera transforms will be optimized for the selected combination of *Camera Spectral Sensitivites* and *Reference illuminant* which minimizes

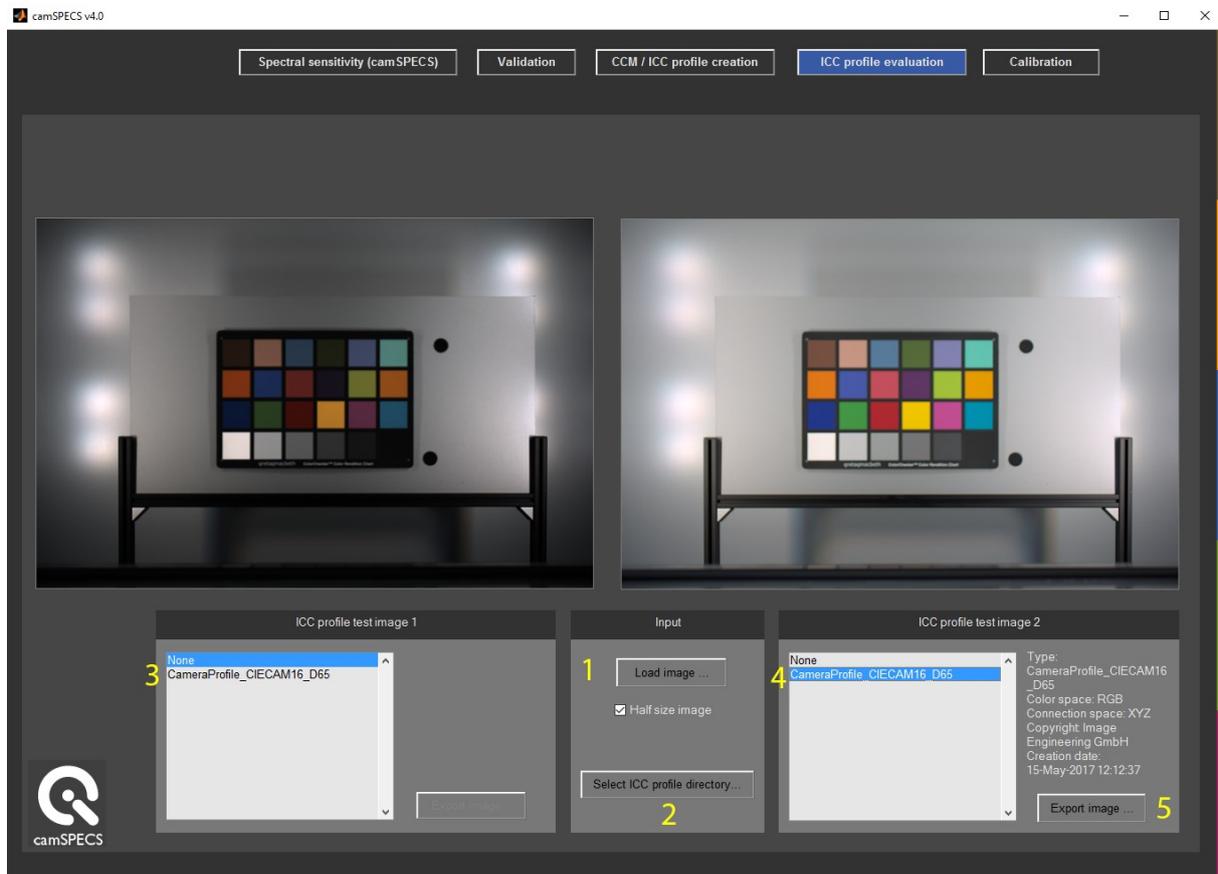


errors in the prediction of the *Training data*.

6. Select the desired reflectance *Test data* which will be used to evaluate the camera transform. Once the camera transform has been computed, these test data will be evaluated through the transform.
7. Optionally, *Additional Test Data* can be selected to input additional test spectra to be used to evaluate the camera transform.
8. Click *Start* to generate the specified transform.
9. The results panel shows the performance of the transform. By default, a visual representation of the *Test data* is shown in split field for each color patch.
10. Display shows the results from the computed transform by default as a *Delta E – Color Comparison*.
11. Click *Export...* to save the transform.



## 4.6 ICC profile evaluation



1. **Load Image...** selects a raw test image captured under the same illumination for which the ICC profile was computed. The image will be opened and converted from raw to white balanced, 16 bit, linear RGB. The Half size image option, if checked, reduces the image size for faster processing and viewing.
2. **Select ICC profile directory...** selects the directory where ICC profiles are located or were saved in the CCM/ICC profile creation module.
3. **ICC profile test image 1** selects from a list of ICC profiles. To view the raw image, select None.
4. **ICC profile test image 2** selects from a list of ICC profiles. To view the image color managed for viewing on an sRGB device, select the ICC profile just created in the CCM/ICC profile creation module.
5. **Export image...** saves the white balanced, 16 bit, linear RGB image with the ICC profile embedded.