camSPECS 2.8

user manual

includes camSPECS and camSPECS express

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CONTENT

1. INTRODUCTION

camSPECS is a solution to measure the spectral response of a digital camera. There are two different hardware devices that can be used interchangeably and one software that does the analysis. camSPECS contains a light source, a set of interference filters and the evaluation software. camSPECS express is a different hardware device, that allows the determination of the spectral response from a single shot. camSPECS express consists of a box with a light source and a front plate with the filters. Both versions include a monochrome camera for the purpose of recalibration.

The camSPECS software is an executable program for MS-Windows or Mac OSX and can be used for both hardware versions.

1.1 Changes since version 1

- Three modules are implemented: spectral response, validation, color correction matrix calculation
- Automatic filter detection
- Automatic RAW conversion
- Batch processing for both versions: multiple images for camSPECS express or multiple series of images for camSPECS
- Provides data sets of standard illumination sources and color checker reflectance
- Added two methods for color correction matrix calculation: Least-squares, white-point preserving least-squares

1.2 Changes since version 2.0

- New GUI design, adapted to iQ-Analyzer
- Support of camSPECS express
- New module “Recalibration”, allows the creation of a new calibration file with the delivered monochrome camera.Changes in the characteristics of the lamp over time can be compensated at any time.

1.3 Changes since version 2.5

- Improvemt of automatical filter detection
- Implementation of Digital Still Camera / Sensitivity Metamerism Index (DSC/SMI)
- Support of non-standard Bayer patterns
- Dark frame subtraction in module 'Validation' available

2. SETUP

2.1 camSPECS

2.1.1 camSPECS - Projector

1. Remove the packaging material.
2. Check that the power supply voltage switch is set correctly to the voltage used in your country. The switch is located at the bottom of the projector.

2.1.2 Interference filters

Put the inference filters into the slide magazine in the right order (0 - 40).The reference channel (ND filter) on each slide must be on the left side, when looking from the camera's point of view.

2.2 camSPECS express

2.2.1 camSPECS express

1. Remove the packaging material.
2. The plug for the power supply and the main switch are located at the back side of the box.
3. The box contains a fan for cooling the box, do not cover the fan-discharge duct on the right side of the box.

2.3 Software setup - PC

1. Unzip the camspecs.zip to a folder.
2. To run the software, 'Matlab Component Runtime' is required. Run 'MCRInstaller.exe' and follow the instructions. This will install the Matlab Component Runtime on your system, if necessary.

2.4 Software setup – Mac OSX

1. Unzip the camspecs.zip to the application folder.
2. Download "MCRInstaller.dmg" from our FTP server **http://www.image-engineering.de/ie-sw/MCR_Installer/** (user: **IE-Analyzer** // pass: **ie47sw11**), open the file and run the MCRInstaller.
3. Run "camspecs_V2.app"
   Note: There can be only be one MCR on your Mac computer. camspecs_V2 will not start if it is not in the applications folder.
   If you want to use it in a different folder:
   - Open Automator
   - Drag and Drop the camspecs_V2..app on the Automator Icon
   - Modify the path in the script that is displayed

3. WORKFLOW

In this chapter the general workflow of spectral response measurements for both hardware solutions is described. For reliable measurements following steps should be prusued. Deviations from this procedure may result in wrong results.

3.1 camSPECS

3.1.1 camSPECS settings

Turn the projector on and let it warm up for a couple of minutes. Put the slide magazine into the projector until it reaches its end-stop. Bring the first filter into the projection slot by using the remote control. Always use the remote control for changing the slides, since doing this manually may result in a different position of the slide. Holding the green button on the remote control longer than 1s changes back to the last slide.

Note: During the warm-up period the lamp may change its spectral behaviour.

3.1.2 Camera settings

Set the camera to manual exposure mode. If a manual mode is not available, use the automatic exposure mode. To get best results it is necessary, that the camera is able to save pictures as linear RAW files.

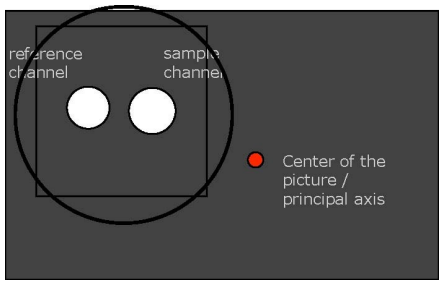
Recommended settings:

Exposure program	Manual / auto
Aperture	Fix aperture when possible (same depth of field)
ISO Speed	lowest
Auto focus	off
File type	RAW

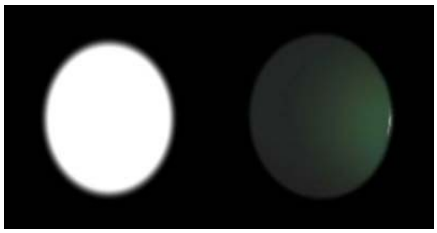
3.1.3 Camera position

Place the camera in front of the projector. Use the first filter slide to adjust the camera correctly. Take a picture of this slide and check if it displays the filters as follows:

The interference filters are reflective, so stray light may affect the measurement. By bringing the filters out of center of the frame, a direct reflection of the reference channel on the sample channel can be avoided.



Shield the camera with some dark cloth to block the room light. To avoid errors due to dust and the grid pattern of the reference filter bring the the picture slightly out of focus.



3.1.4 Exposure

To get sufficient results the pictures of the filters may not be overexposed.
To decide which exposure setting is appropriate insert the filter with the highest intensity (one of the filters from 530 – 560 nm). Take a picture of the filters with equal exposure settings. Check the green channel to have a high digital value without being saturated. One of the filters in this range should have the highest intensity in case of usual consumer cameras. When testing special cameras, like infrared cameras, one has to test possibly all filters to find out the brightest one.
When using the auto exposure an exposure correction might be necessary. The evaluation software can use the camera's EXIF data or manually entered exposure data to correct the different exposure levels.

Note: A good starting point is 1/10sec, f-stop 5.6 at ISO 100 (= 8.3 EV).

3.1.5 Photographing the filters

Take pictures of the filters in series. Use the transportation system of the projector (green button on remote control) to change the filters.
Do not change the order of the filters. Do not alter the position of the camera during one series of measurement. The supplied calibration data of the software will only work with all filters inserted.

3.2 camSPECS express

3.2.1 camSPECS express settings

Switch the box on and let it warm up for a couple of minutes.

Note: During the warm-up period the lamp may change its spectral behaviour.

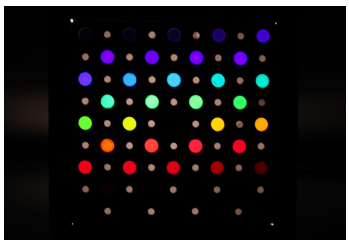
3.2.2 Camera settings

Set the camera to manual exposure mode. If a manual mode is not available, use the automatic exposure mode. To get best results the camera shall be able to save pictures as linear RAW files.

Recommended settings

Exposure program	Manual
Aperture	No default value
ISO Speed	Lowest value
Auto focus	Off
File type	RAW

3.2.3 Camera position and lenses used



Place the camera in front of the box. The principal axis of the lens shall be aligned perpendicular to the the center of the filter plane. The distance between the lens and the filter plane depends on the focal length. The picture of the filter plane shall cover all filters with some distance to the margins of the picture. 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° do not cause noticeable impacts on the resulting spectral responses.

Important: 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 express box should be shielded.

3.2.4 Exposure

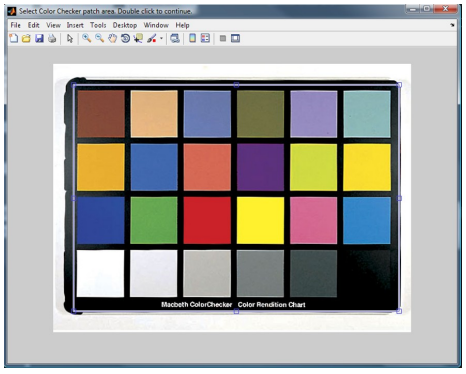
To get correct results the picture of the filters may not be overexposed. Take a picture with reasonable exposure settings. Check the brightest filters for the highest intensity in all RGB channels. There shall be no filter saturated in one of the channels. Choose exposure values so that there is no saturated RGB channel in any filter and that at the same time the brightest channel has a reasonably high digital value.

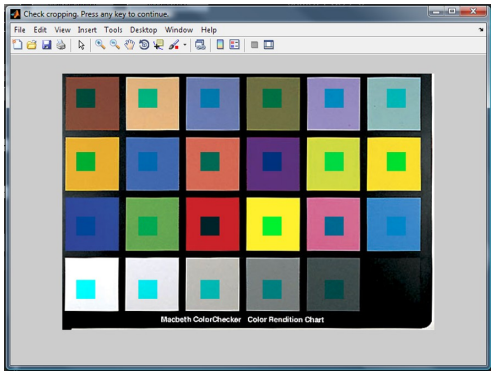
3.3 Spectral measurement

- Start the camSPECS software and switch to module 'Spectral response'.
- Check the advanced settings (see chapter 4.2) if the default settings comply with your needs.
- Choose a calibration file which corresponds with your hardware (camSPECS or camSPECS express), you can add a new file and delete a file from the menu using the corresponding buttons.
- Check all other settings to comply with your needs (e.g. 'use EXIF data' or choose a dark image).
- Select and add the images with the '+' button.
- Click the 'Start' button.
- Check the result of the automatic detection and confirm it by double clicking on the image outside the ROIs (Regions of interest).
- The result of the measurement is displayed and a text file with the name of the first image (camSPECS) or the name of the image (camSPECS express) is saved to the same folder as the images.
- See detailed information on this module in chapter 4.2.

3.4 Validation

- Take a picture of a ColorChecker (24 or SG) chart that is illuminated by a light source with a spectral distribution whose database is implemented in the software (see item 1 in chapter 4.3).
- The picture shall have uncompressed RGB data.
- Choose a spectral response file in the module 'Validation'.
- Select the light source and a reflectance data file for the ColorChecker.
- Select the picture of the ColorChecker chart.
- Select optionally a dark frame for correction
- Click the 'Start' button and draw a rectangle around the patches in the image.
- Double click on the image and check in the next step the correct position of the ROIs. Click to continue.
- The graph displays the measured RGB values for each patch plotted against the predicted values.
- See detailed information on this module in chapter 4.3.





3.5 CCM calculation

- Select the spectral data of a light source, the ColorChecker training data and a measured spectral response file in the corresponding menues and input fields.
- The camera settings are only used for the CIECAM02 algorithm.
- Click 'Start' and the three matrices are calculated and displayed.
- You can save all data to one text file by clicking on the 'Save matrices' button.
- See detailed information on this module in chapter 4.4.

3.6 Recalibration

- Select a spectral response file and the reference file delivered with the CD.
- Click on 'Compare' to compare both curves plotted in the graph.
- Click 'On-site calibration' to compare both curves and create a new calibration file, which is saved to disk and which is available immediately in the pop-up menu 'Calibration file' in the 'Spectral response' module.
- To check the recalibration you can again test with the same images and the new calibration file and the compare the new spectral response result with the reference file.
- See detailed information on this module in chapter 4.5.

4. SOFTWARE

In the main window you can choose which operation you want to perform.

4.1.1 Image data

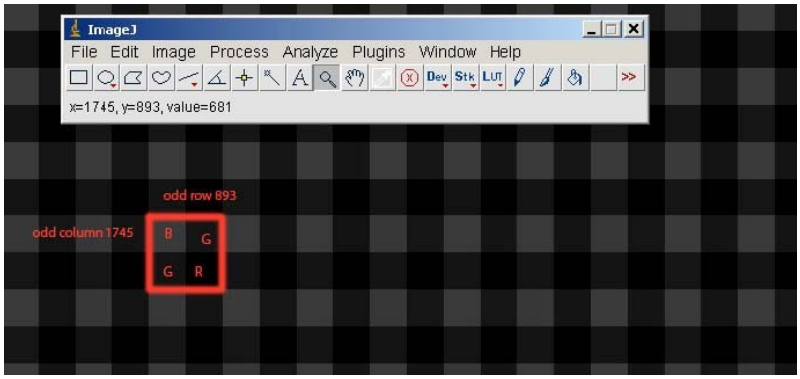
The camSPES software can handle Bayer pattern data or demosaiced image data independent from the file type. If you use your own RAW converting software you should convert the images to TIFF files by maintaining the Bayer pattern. You can also use the program 'dcraw' to convert D-SLR camera RAW files, the latest release is delivered with camSPECS. If you do not have access to raw files camSPECS can handle RGB images.

If RAW files are selected the RAW processing is performed automatically for all images selected in every module. The files are saved as TIFF files to a subfolder of the location of the original files, named “converted”. These images are used automatically for the subsequent processing. If further tests with the same image or image sequence shall be accomplished you can choose the converted images.
Images are converted retaining the original Bayer pattern.

Note: See http://www.cybercom.net/~dcoffin/dcraw/ for list of all supported cameras. On this site you will also find a link to executable versions of 'dcraw'. To update 'dcraw' just replace the 'dcraw.exe' with the new one.

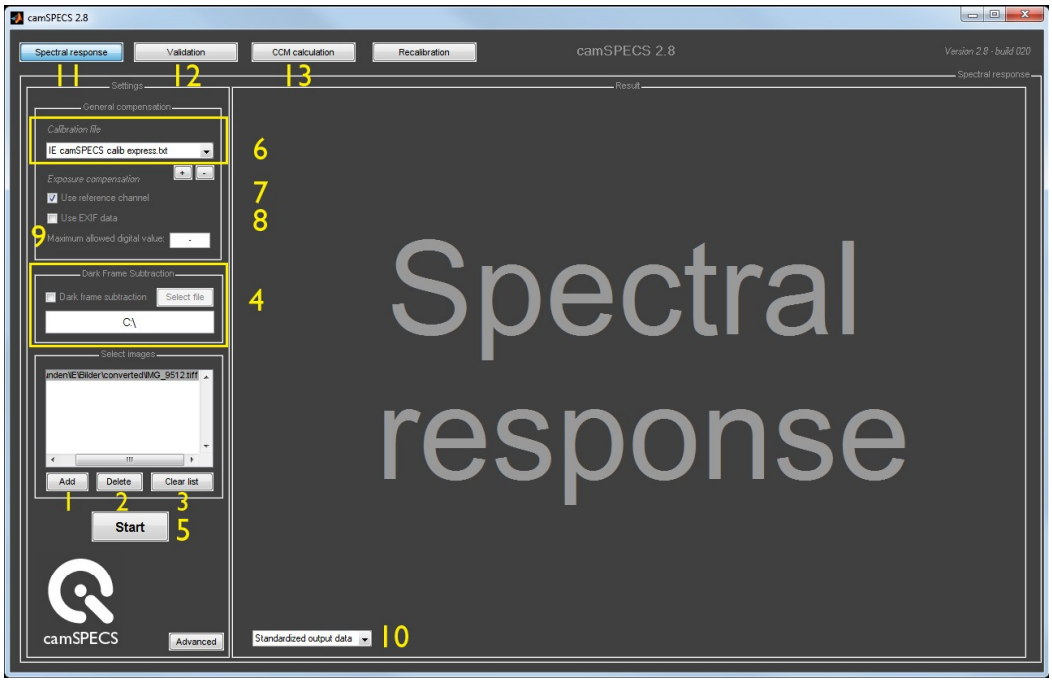
4.1.2 Color filter array

Sometimes it might be necessary to set the CFA manually (see 4.2.1). To figure out how the pixels are located in the CFA open the images of the filters 450nm, 550nm and 650nm (projector version) with an image processing software (e.g.: ImageJ). Or look at the corresponding filters in an image taken with camSpecs express. These filters represent blue, green and red. (Non-standard color filter arrays are supported since version 2.8, you can select 'C' (for Clear) for each channel in the drop-down menues in the advanced settings. (see chapter 4.2.1))



If you have a close look at the CFA in the 450 nm picture, the brightest pixel is blue.
The brightest pixel in the 650 nm filter picture is red. The remaining two pixels of a 2x2 area represent the green channel of the camera. This procedure should work with most regular 3-channel cameras. The camSPECS software always uses odd pixel positions to avoid mixing up the color channels.

4.2 Spectral response module



1. 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 will have to convert these files to 16-bit Tiff images first.). Depending on the selected calibration file (6) you can choose one or more images that have to contain the filter arrangement either of camSPECS express or camSPECS.
2. Remove single image from the list.
3. Remove all images from the list.
4. Dark frame subtraction. If you have a dark frame, select it here. 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. Starts the processing. In both versions, camSPECS or camSPECS express, 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 (figure 1). By double-clicking on the background the processing starts. A tile image, assembled from all images of the camSpecs version, is saved to the same folder as the current selected source folder (figure 3). The result is displayed on the panel and saved to a text file in the same folder as the original image folder.
6. Select the calibration file for your camSPECS or camSPECS express hardware. Via the '+' and '-' buttons calibration files can be added and removed from the list. When removed from list the original file is not deleted from disk.

Note:

The neutral density (ND) filters adjacent to the interference filters are used as a brightness reference for correction of different exposure levels. Such differences may be caused by using automatic exposure control or imprecise working shutter or aperture control of the camera in case of camSPECS. For camSPECS express remaining inhomogeneities of the irradiation device are corrected by the nearest neighbor ND filters.

The selected calibration file in the menu must correspond to the images selected. If a camSPECS calibration file is selected the program expects camSPECS images in the image list. That means that there must be as many images selected as there are rows in the calibration file.
If you have your own calibration data, the calibration text file has to be formatted as follows (Table 1, only the colored cells are saved in the text file):

Wavelength (nm)	Power of color filters	Power of neutral density filters
380	49.1	1316
390	110.7	1286
400	181.7	1287
410	208.3	1295
…↓	…↓	…↓
700	297.6	1308
710	321	1283
720	286	1294
750	1345	1289
800	1076	1310
850	996	1312
905	408	12

Table 2: Formatting of the calibration file for camSPECS express: the rows contain values for the wavelength and the power of the color filters and the ND filters alternating from line to line. “1” stands for the ND filter. The corresponding filters on the panel are numbered from the upper left side to the lower right side (see figure 1).

Wavelength (nm) of the color filters, resp. ‘1’ for the ND filters	Power of the filters
380	105
1	3580
390	101.8
1	3520
400	86.7
1	3450
410	66.6
1	3440
…↓	…↓
570	92.4
1	3300 *
1	3180 *
580	95.0
…↓	…↓
1	3540
850	79.4
1	3560
905	60.0

* Center filter arrangement, two subsequent neutral filters (see figure 1)

7. Use the reference channels (neutral density filters) to correct for exposure differences.
8. Use EXIF data for correction of different exposure settings. This is necessary when the automatic exposure control of the camera is used.
9. Set the maximum allowed digital value.
10. When the measurement is done you can switch between raw and normalized RGB output data.
11. Switch to module “Validation”.
12. Switch to module “Color Correction Matrix”.
13. Switch to module “Recalibration”.

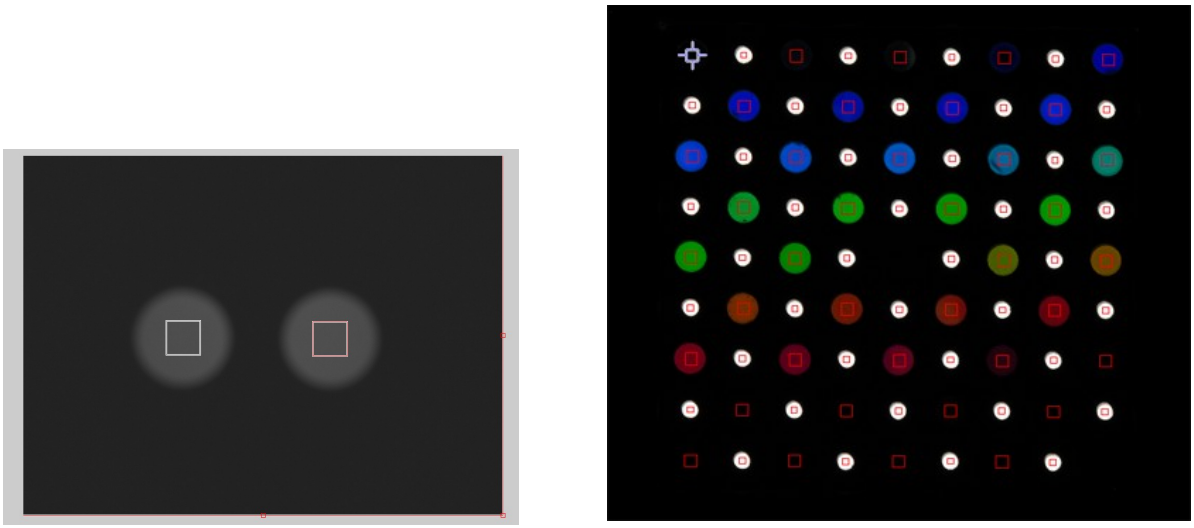


Figure 1 Automatic detection of the filters in camSPECS and camSPECS express. The ROIs shown in this example were set to an edge length of 50% of the diameter of the corresponding filters (see chapter 4.2.1, section 5).

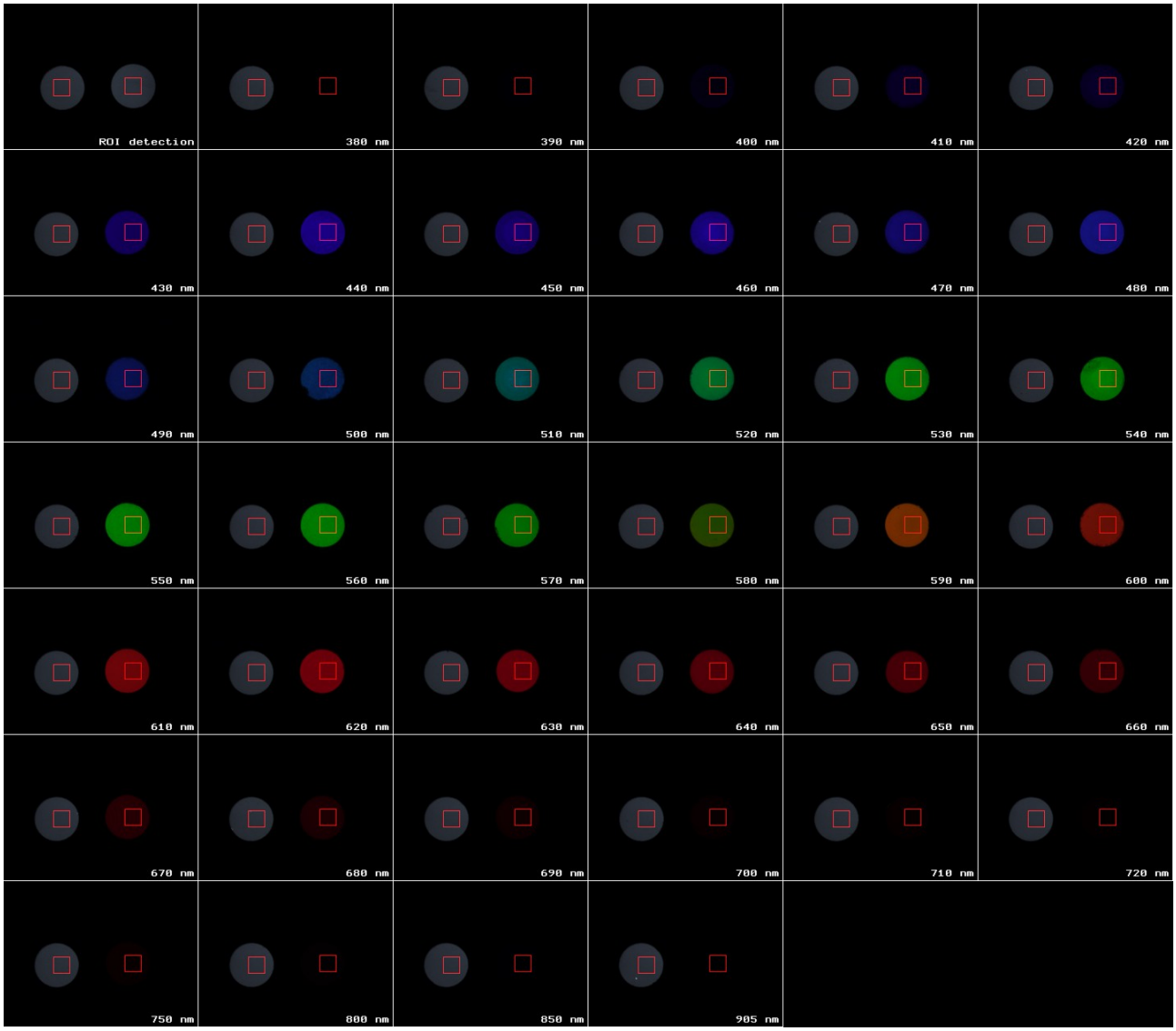
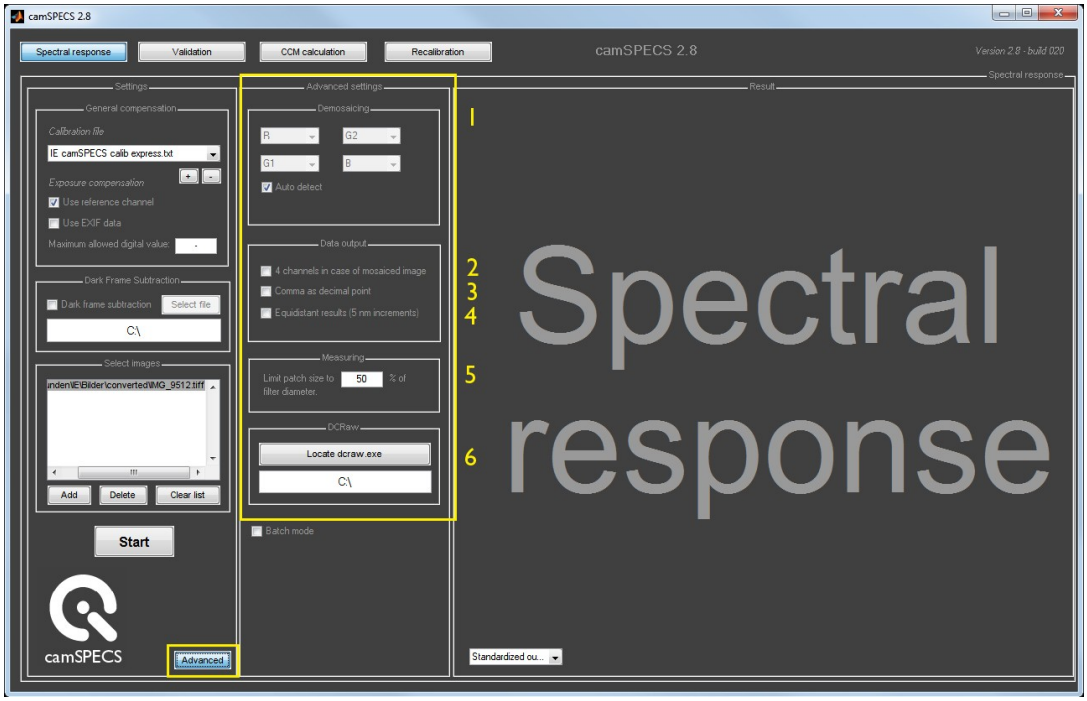


Figure 3 A tile image is created from all images of a series. Displaced filter frames can be identified easily.

4.2.1 Advanced settings



1. The software detects the color filter array (CFA) automatically. Disable the option “auto detect” to set the color filter array manually. If there is a CFA that is not a standard pattern consisting of R, G and B, for example a pixel without a filter, C (Clear) can be chosen. In this case all four channels are measured separately and displayed as four different channels without any assignment to a color.(see figure 4).
2. To get 4-channel results use this option (does not work with RGB files).
3. Use decimal comma in the resulting text file.
4. Interpolate the spectral response data to increments of 5 nm when selected. Standard is 10 nm if this option is not selected. 5 nm data are necessary for further processing in the modules “Validation” and “CCM calculation”.
5. Size of the ROI for the measurement in every filter in relation to the diameter of the filters. Standard setting is 50%. Selecting higher values may result in inaccurate results, since vignetting may occur close to the borders of the filters. The minimum size is checked for a size of more than a hundred pixels for statistical significance and the program gives a warning.
6. Select the dcraw.exe*. A current version is delivered with camSPECS and is located in the folder “app” inside the camSPECS program folder. The RAW processing module of the camSPECS software uses 'dcraw' to convert common RAW files to TIFF files. When images are converted from RAW to TIFF the original files are not deleted.
7. If the “Batch mode” button is selected the program runs the test in batch processing. That means if there are multiple images of camSPECS express, all images are tested in series and if there are multiple image sets of camSPECS all series are tested subsequently. The automatic detection is moreover not interrupted by a confirm dialog when running in batch mode.

Note: A long file-path or a network path can cause problems. Use short paths. (for example: C:\program files\dcraw). See http://www.cybercom.net/~dcoffin/dcraw/ for list of all supported cameras and for the current version of 'dcraw'.

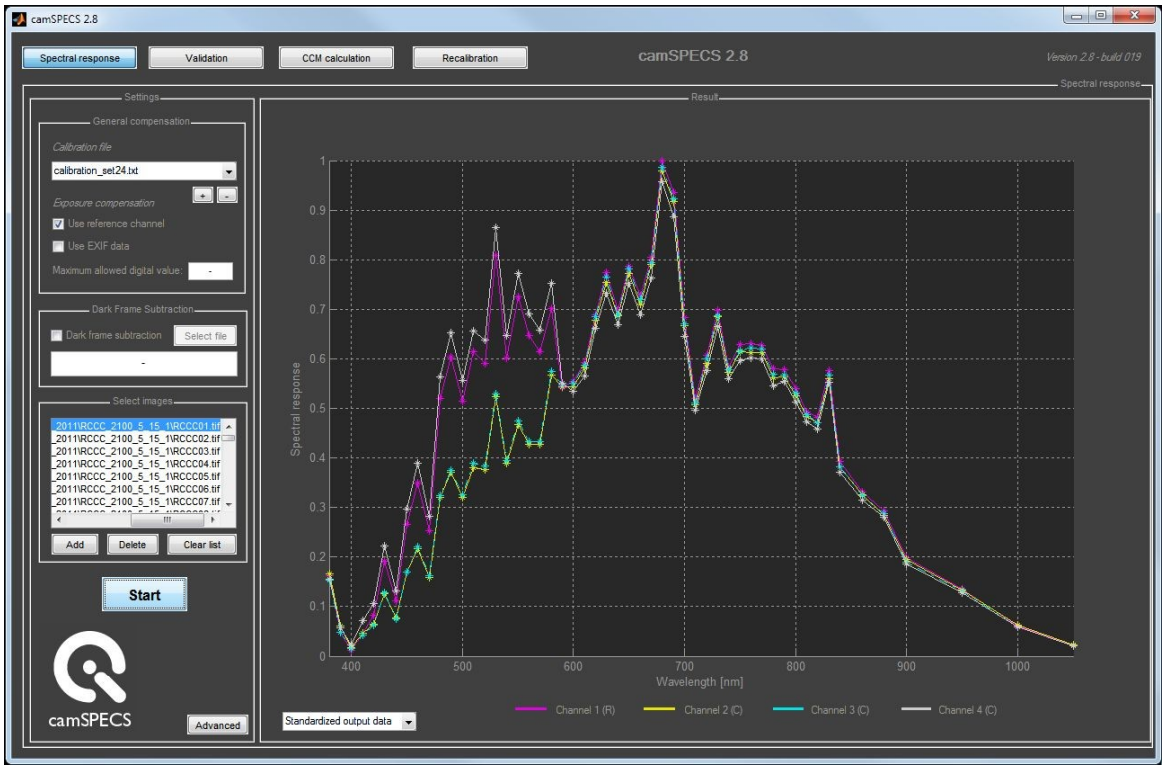
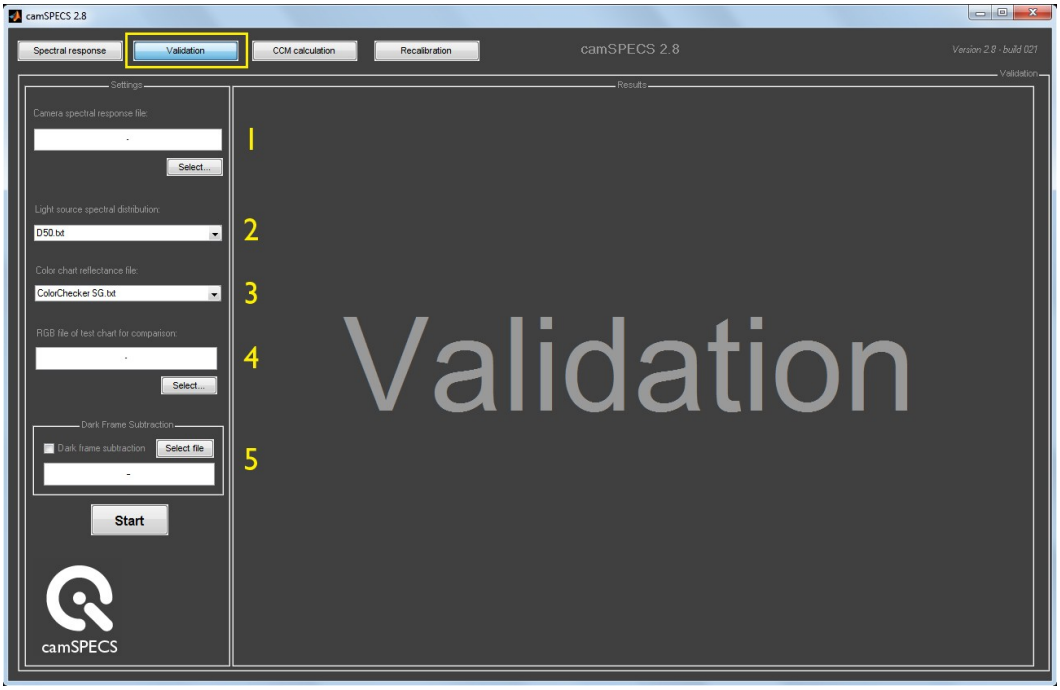


Figure 4: Spectral response of a non-standard color filter array: R-C-C-C

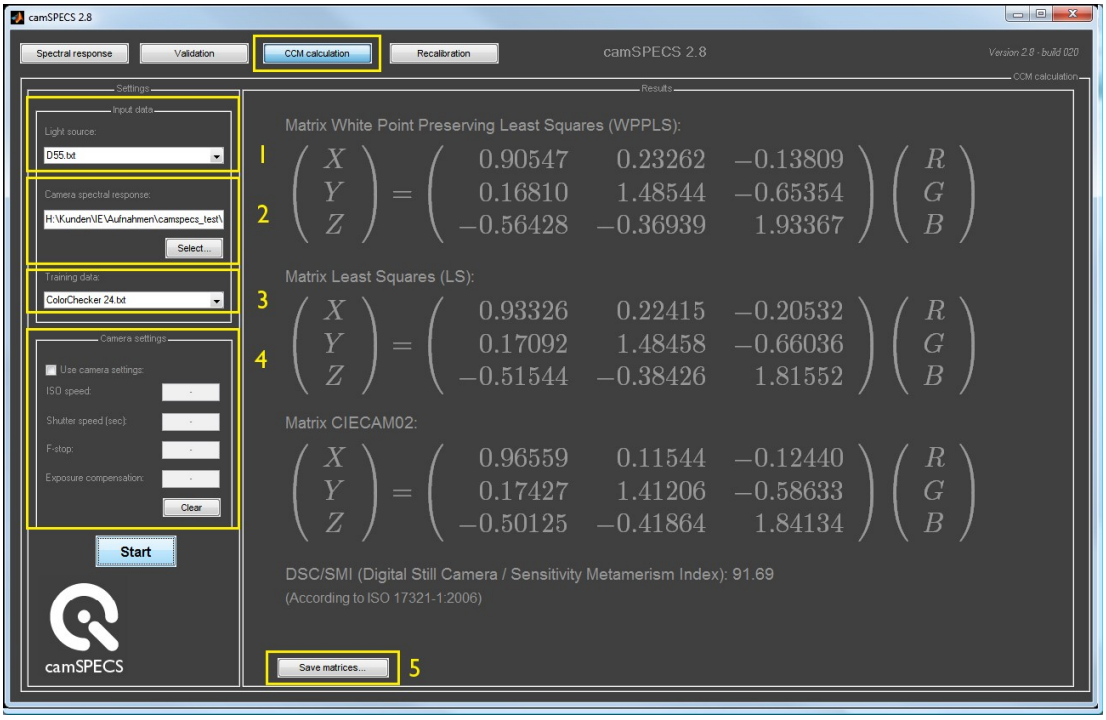
4.3 Validation module



1. Select a file with the result of a spectral response measurement with data interpolated to 5nm (see advanced settings).
2. Select a spectral distribution file for the light source used for the illumination of the test chart.
3. Select a color chart reflectance file. The files contain the spectral distribution between 380nm and 730nm in five nm increments.
4. Select an RGB file of a ColorChecker test chart (ColorChecker with 24 patches or ColorChecker SG with 140 patches).
5. Here you can select a dark frame for subtracting from the ColorChecker image (see 4.).

After clicking the “Start” button the selected ColorChecker image is opened and displayed. You can select the color chart by drawing a rectangle around the patches from upper left to lower right and double click on the background. The regions of interest for each patch are displayed in the next step. Click to continue.
In the displayed result the measured digital values (red, green and blue) for each patch are plotted against the predicted digital values. The axes are normalized for the maximum digital value to 1.
If the measurement was correct all RGB data points should be close to the white diagonal line.
Possible reasons for major variations are changes in the illumination of the target, or in manipulations of the RGB data within the camera.

4.4 Color Correction Matrix module



1. Select a spectral distribution file for the light source used for the illumination of the test chart.
2. Select a text file with the result of a spectral response measurement with data interpolated to 5nm (see advanced settings).
3. Select a color chart reflectance file. The files contain the spectral distribution between 380nm and 730 nm in five nm increments. Other data can be used if the data structure complies with the data used here. New files can be added to the folder in the camSPECS software (/calibration_files/reflectance).
4. When the check box ('Use camera settings') is selected you can enter the camera settings for the ISO speed, shutter speed, F-stop and the exposure compensation. These values are used in the calculation of the color correction matrix with the CIECAM02 algorithm.
5. The resulting matrices can be saved to a text file. The columns are tabulator separated.

Three different algorithms for calculating the matrices are incorporated:

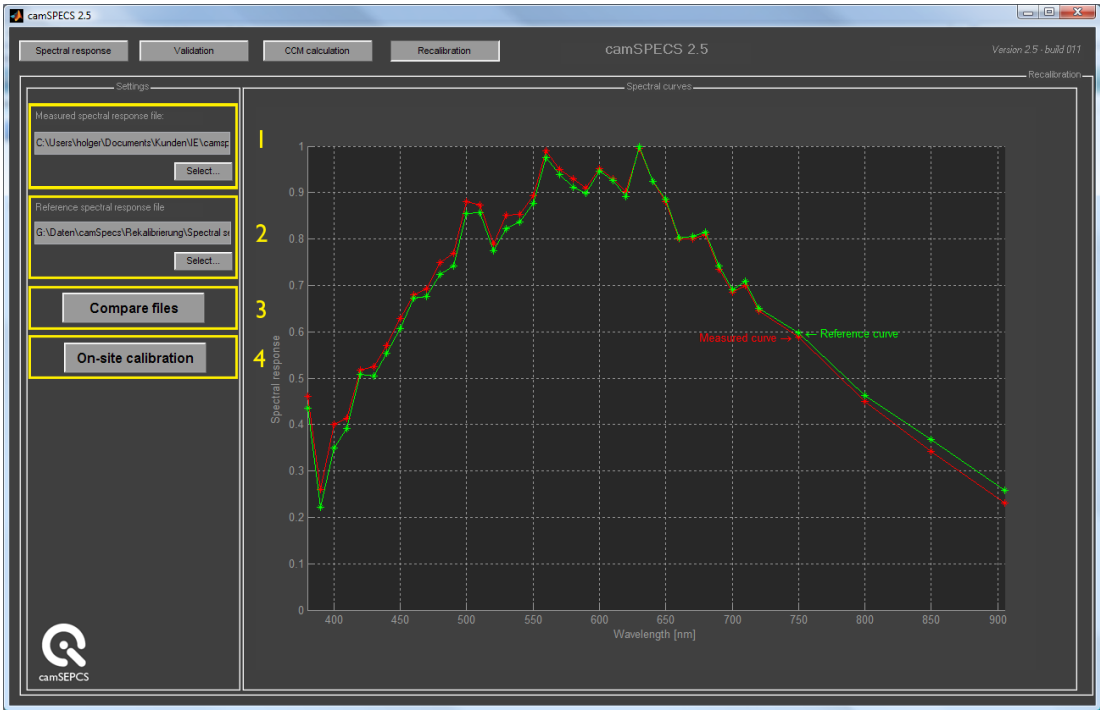
- *Least-squares linear regression (LS):* With is method the overall residual squared error is minimized. It makes no statement about which colors will be mapped well and which will be mapped poorly.
- *White-point preserving least-squares (WPPLS):* This method preserves the achromatic (white and gray scale) colors. It may deliver poorer color correction compared with the LS procedure, but squared error need not necessarily correlate with perceived visual error. This procedure is described in: Graham D. Finlayson and Mark S. Drew. *White-point preserving color correction,* The Fifth Color Imaging Conference: Color Science, 1997.
- *CIECAM02*: The CIECAM02 color appearance model is based on CIECAM97s and was published in 2002 by the CIE Technical Committee 8-0 (Nathan Moroney et al. The CICAM02 Color Appearance Model, IS&T/SID Tenth Color Imaging Conference). It includes revisions and simplifications of the transforms of the CIECAM97s model.

Additional measurement of DSC/SMI (Digital Still Camera / Sensitivity Metamerism Index) :

- DSC/SMI is designed to give a measure for potential colour errors caused by real cameras reproducing different sensor outputs for two objects having the same tristimulus values but different spectral distributions.
- The implemented Average DSC/SMI will give a measure of camera metamerism for ordinary reflective objects. In this definition eight colour patches represent reflective objects.
- The index ranges from 0 to 100 (best).
- Reference:
  ISO 17321-1:2006 (E), International Imaging Industry Association (I3A),
  701 Westchester Avenue, Suite 317W, White Plains, NY 10604 USA.

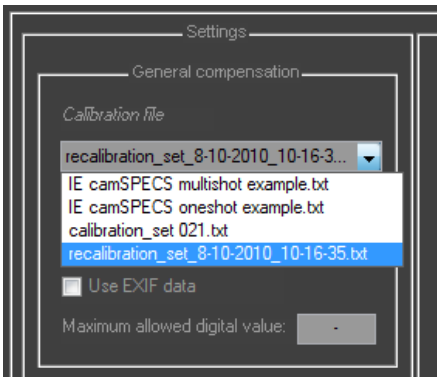
Note: The selected training data and the camera settings are not used for calculation of the DSC/SMI, the spectral data of the eight color patches are implemented permanently in the program.

4.5 On-site recalibration

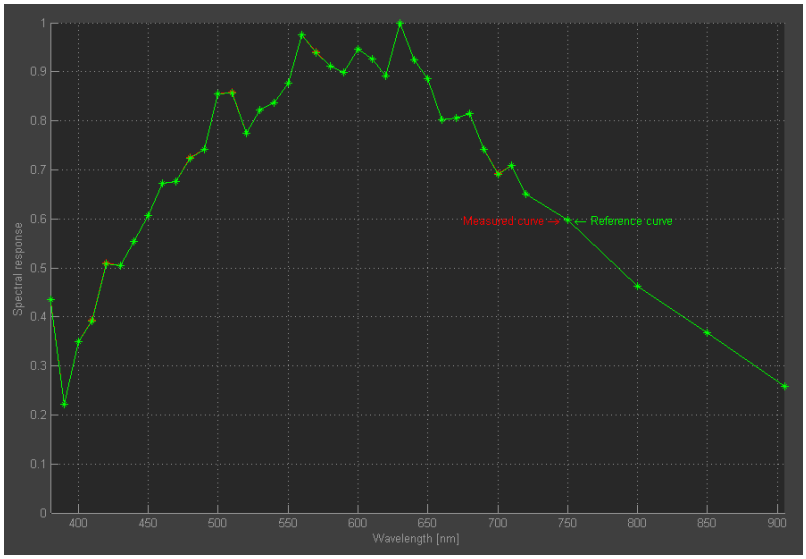


If you have the monochrome camera for your camSPECS hardware, you can perform a recalibration. A recalibration is recommended primarily due to changes of the radiation characteristics of the lamp over a long period. Since version 2.5 of camSpecs the module “Recalibration“ allows you to compare a current spectral response measurement made with the monochrome camera to the reference measurement delivered with the CD. The reference file can be found in the folder “Intensity calibration file” on the CD (the name of the file is for example: Spectral sensitivity Lu175M-IO#10050045_specs, with different serial numbers).

In the module “Recalibration” you can select two files, one of a current and one of the reference measurement (1/2). Clicking on the button “Compare files” (3) draws both spectral sensitivity curves on the panel. The button “On-site recalibration” (4) does the latter and additionally calculates a new calibration file which is immediately available in the menu “Calibration file” in the “Spectral response” module. The file name contains the date and time of the recalibration and is called: “recalibration_dd-mm-yyyy_hh-mm-ss.txt”. To validate the recalibration process you can run a new spectral response measurement (with the same images), switch to the recalibration module and compare the new result file to the reference file. Both curves are now supposed to have the same progression.



The new calibration file is immediately available



Validation of the recalibration with the same images

5 KNOWN ISSUES

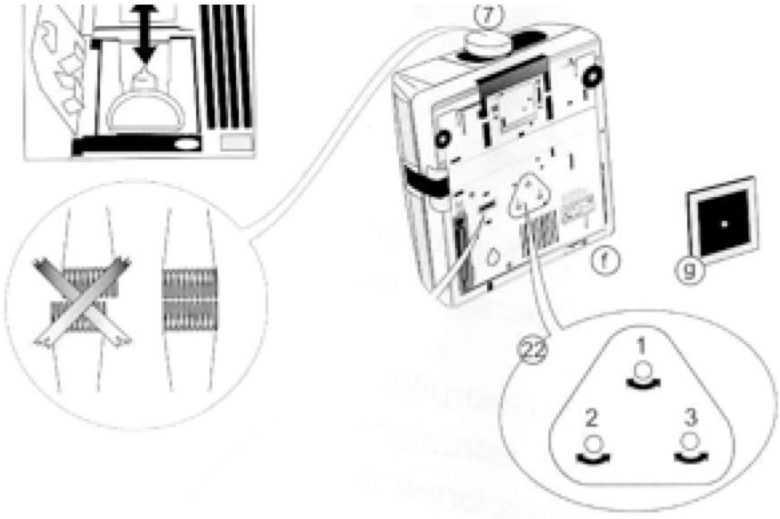
PC: A long file-path or a network path can cause problems when using 'dcraw'. Use short paths on your computers hard drive for your images.

Mac OSX: Make sure to copy the content of the .zip file into your applications folder. If you need to have it running somewhere else, please run „Automator“ (in you applications folder) and drop the camspecs_V2.app on the icon. You can now edit the folder to your needs. Save after changing the path.

6 HARDWARE - INFORMATION

6.1 Adjusting the lamp

- Open the lamp housing and remove the diffuser plate.
- Place the projector on its back in vertical position with the lens hole pointing upwards.
- Cover the lens hole with a sheet of thin white paper.
- Insert the perforated slide using the slide lift.
- Switch the projector on. You can see the filament of the lamp twice on the paper.
- The filaments must have the same size and must overlap exactly. The position can be adjusted with the knobs at the bottom of the projector.
- Switch the projector off and reinsert the diffuser plate.



Adjusting the lamp

6.2 Projector modifications

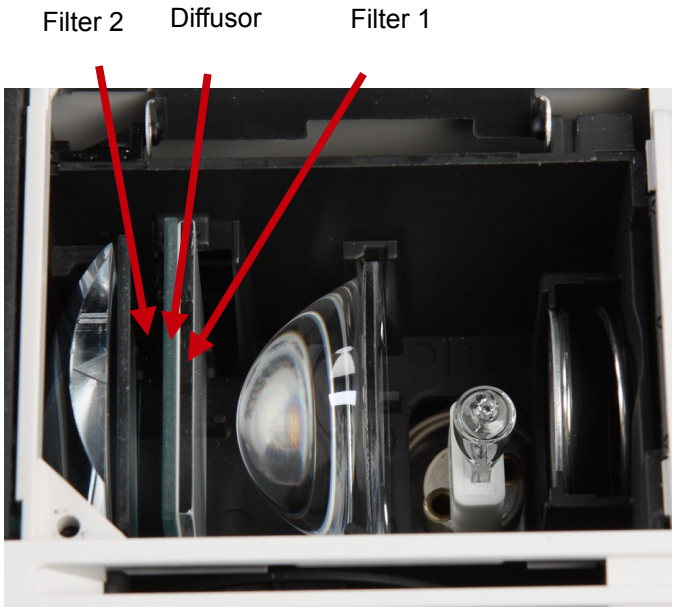
The projector contains three modified filters, one for converting the spectral distribution of the lamp to a more continuous spectrum, one for heat protection and a diffusor. If you remove filters for cleaning or any other purpose, put them back into the original position as described below:

1. Filter 1 (colorless), for heat absorption
2. Diffusor, improves uniformity of the illumination in the filter plane
3. Filter 2 (blue), color conversion filter

The combination of both filters model the output of the light in the range of 350 nm to 950 nm in a way that reduces the contrast ratio between the brightest and the darkest interference filter from 1:300 to 1:8. The brightest filter is thus the one with 540 nm.

See detailed information in the data sheet.

Arrangement of the filters in the illumination device



7 TECHNICAL DATA

camSPECS is an all in one solution to measure the spectral response of a digital camera system. It contains the hardware and software tools which are necessary to perform the measurement.

camSPECS

camSPECS express

HARDWARE

camSPECS	camSPECS express
Illumination device	Illumination box with filter panel
A set of interference filters mounted in a small plate together with a reference filter	
For both versions: Monochrome camera and appendant software	

SOFTWARE

- RAW file conversion / dark frame subtraction
- Spectral response measurement
- Calculation of 3x3 color correction matrices with three different algorithms
- Camera RGB comparison to evaluate the accuracy of the measurement
- Recalibration with the monochrome camera

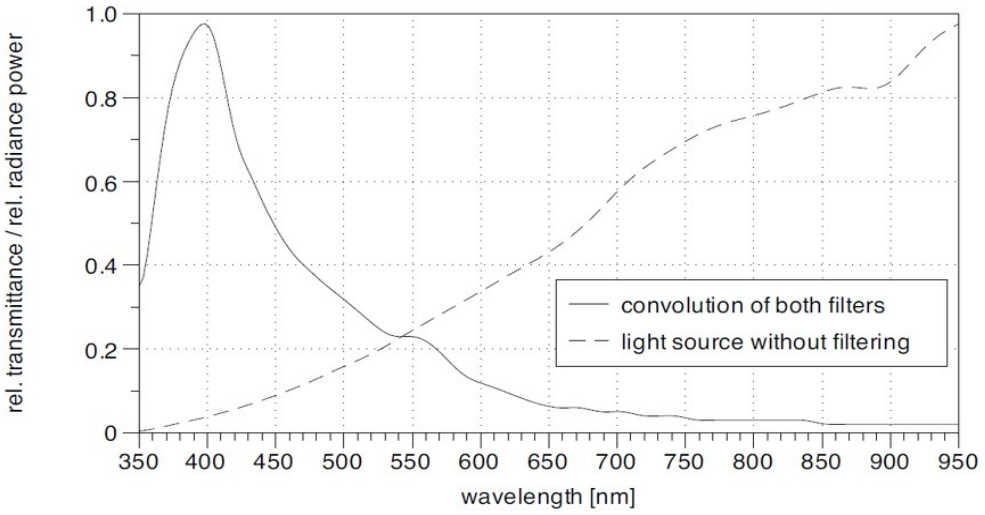
Calibration data for use with the camSPECS software is provided for each set of filters and lamp combination.

7.1 Hardware – camSPECS

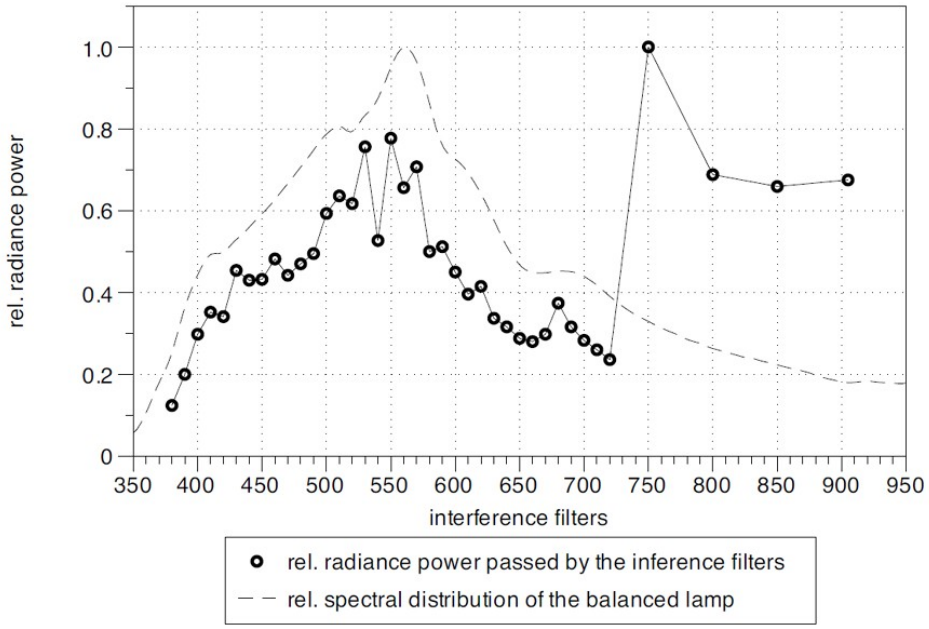
Illumination

The illumination system is a customized slide projector with a stabilized light source. Due to the stabilization of the power supply the spectral distribution of the light source is not affected by fluctuations of current.
The slide transportation system of the projector is used to move the filters subsequently into the light path. Instead of the lens, a tube lined with black cloth to reduce stray light, is used. The camera to be tested is mounted directly in front of the projector and photographs the interference filters.

Light source	Halogen (24V / 55W) JCD24V55WDX
Durability of light source	1000 h
Voltage supply	Adjustable 100-230 V, 50-60 Hz
Stabilization factor	1%
Power input	Approx. 150 W
Dimensions (w x h x d)	291 x 136 x 304 mm
Weight	6 kg
Distance filters to leading edge of the device	12.5 cm



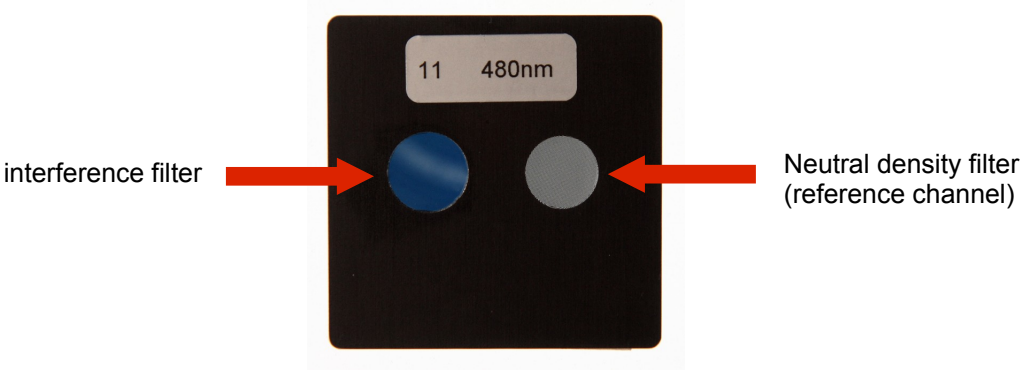
Relative spectral power distribution of lamp and relative transmittance of the filters



Relative spectral power distribution of the filtered lamp and relative radiance power of the interference filters

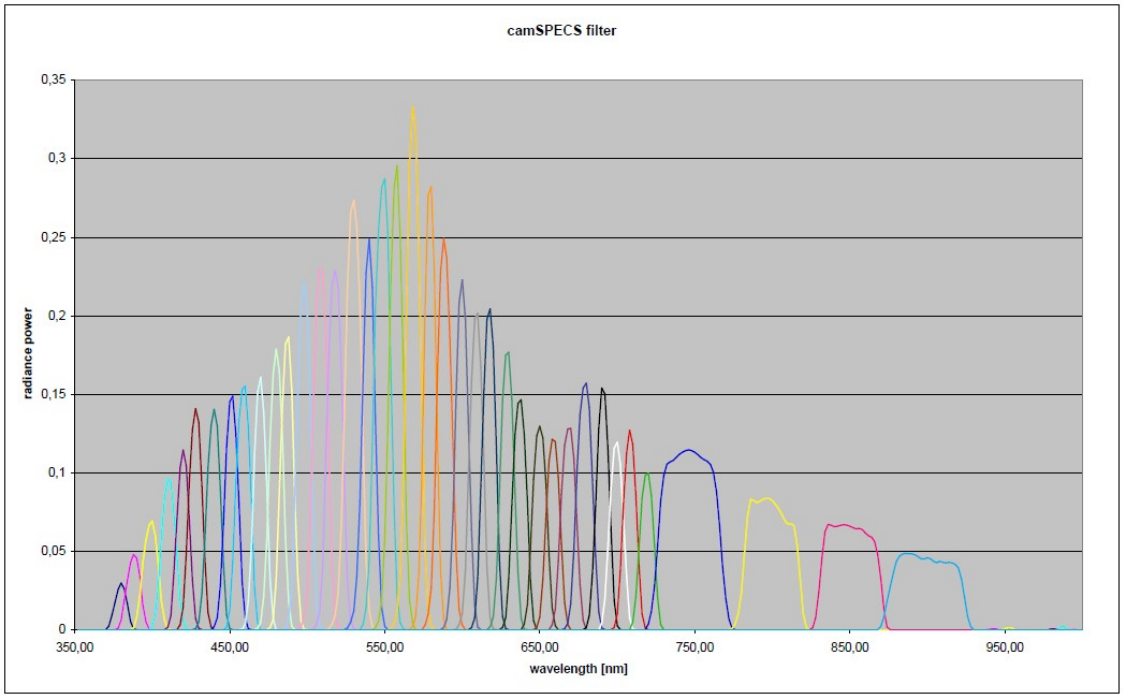
Interference filters

A set of 39 interference filters is used to generate narrow-band light. The filters cover the range of 380 - 720 nm in 10 nm steps and subsequently filters with 750, 800, 850 and 905 nm. The filters are mounted on metal plates with a size of a regular 35mm slide. Aside from the interference filter there is a neutral density filter which is used as a brightness reference to correct for exposure differences.



One of 39 camSPECS filter plates with interference filter and reference channel

Wavelength range	380 - 720 nm (10 nm steps), 750, 800, 850 and 905 nm
Bandwidth	10 nm (380 - 720 nm), 40 nm (750 nm), 50 nm (800 - 905 nm)
Off band rejection	4.0 optical densities
Diameter	12.5 mm



Relative radiance power of the interference filters

7.2 Hardware – camSPECS express

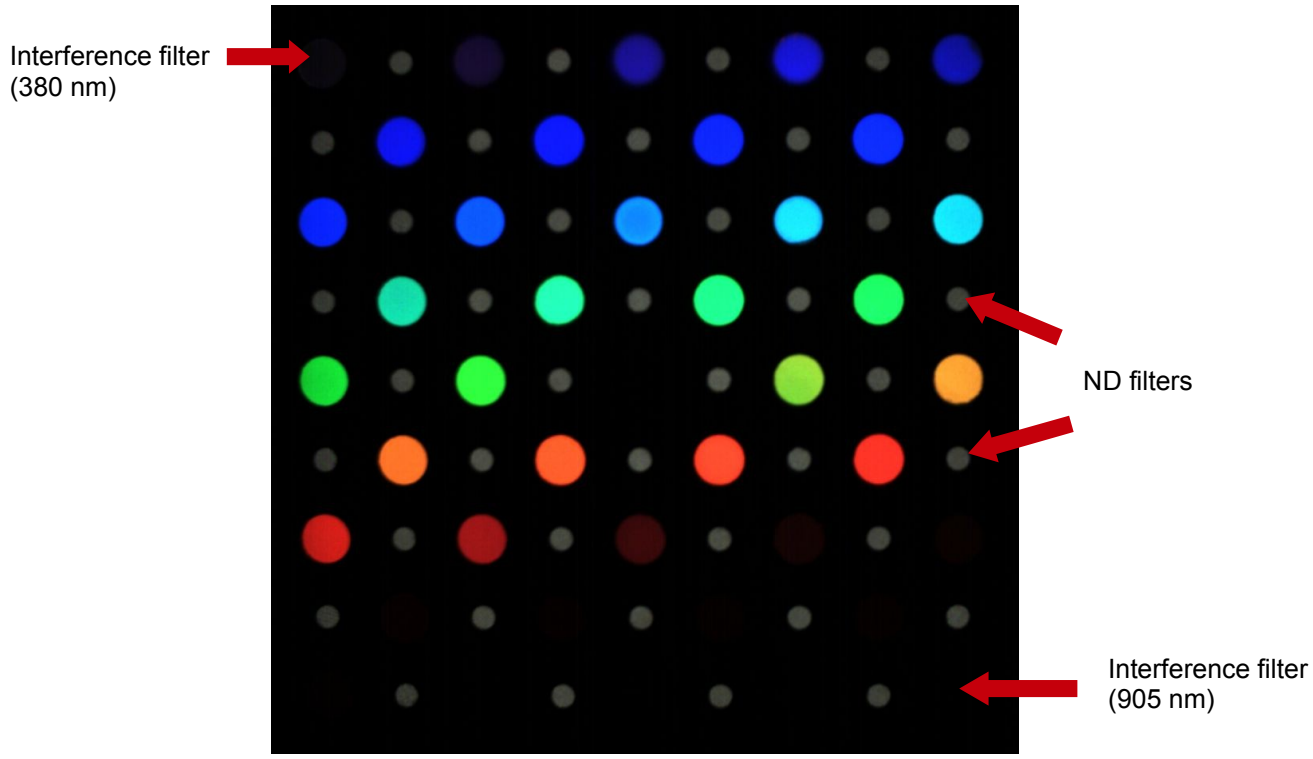
Illumination

The illumination system of the camSPECS express box contains a stabilized light source. Due to the stabilization of the power supply the spectral distribution of the light source is not affected by fluctuations of current.

Light source	Halogen (24V / 250 W), Osram 64655 EHJ
Durability of light source	50 h
Color temperature	3550 K
Luminous flux	10.000 lm
Voltage supply	Automatic adjustable 110 - 230V, 50-60Hz
Stabilization factor	1%
Power input	Approx. 300 W
Dimensions (w x h x d)	295 x 295 x 540 mm
Weight	7 kg

Filter panel

A set of 39 interference filters is used to generate narrow-band light. The filters cover the range of 380 – 720 nm in 10 nm steps and subsequently filters with 750, 800, 850 and 905 nm. The filters are mounted on the front plate of the camSPECS express box. The arrangement of the filters can be seen on the following figure, the series start with 380 nm on the upper left side and continue line by line to 905 nm. In between located are the ND filters.



Wavelength range	380 - 720 nm (10 nm steps), 750, 800, 850 and 905 nm
Bandwidth	10 nm (380 - 720 nm), 40 nm (750 nm), 50 nm (800 - 905 nm)
Off band rejection	4.0 optical densities
Diameter interference filters	12.5 mm
Diameter ND filters	8 mm

7.3 Software

The evaluation software is a Matlab© based Windows or Mac OS X program. To run the program the Matlab Component Runtime (MCR) is necessary. The MCR is distributed together with the software.

System Requirements

	Windows (32bit and 64bit)	Mac
Operating Systems	Windows XP Service Pack 2 or 3 Windows Server 2003 Service Pack 2 or R2 Windows Vista Service Pack 1 or 2 Windows Server 2008 Windows 7	Mac OS X 10.5.5 (Leopard) and above Mac OS X 10.6.x (Snow Leopard) and above
Processors	Intel Pentium 4 and above Intel Celeron** Intel XeonIntel Core Intel Atom** AMD Athlon 64** AMD Opteron AMD Sempron**	All Intel-based Macs
RAM	2048 MB (4096 MB recommended)	2048 MB (4096 MB recommended)

RAW conversion

This module is a batch processing tool which can use 'dcraw' to convert most RAW files to TIF files. You can find a list of all supported cameras at: http://www.cybercom.net/~dcoffin/dcraw/

Standard processing is the conversion to undemosaiced, linear tiff files. To suppress fixed pattern noise a dark frame subtraction (DFS) can be performed. The DFS will subtracts a dark frame from all files of the batch. The DFS can be performed with already converted files. Supported file types are: tiff, tif, bmp, pgm, ppm, png. The RAW conversion module reads the EXIF data from the files, shutter speed, f-stop and ISO speed are used for several calculations.

Spectral response measurement

This module reads the pixel values from the pictures of the interference filters and does the data processing. It can handle undemosaiced (with bayer pattern) and RGB image files. Supported file types are: tiff, tif, bmp, pgm, ppm, png.

The user selects the folder containing the image files of one series of measurement. The software reads the pixel values in the reference and sample channel area. It detects the Bayer Color Filter Array (CFA) automatically. The values are averaged and corrected for the differences in radiance power of the interference filters. Additional processing is the correction for different exposure levels using the reference channel and EXIF data. The results are written to a txt-file. This file contains the final spectral response data, unprocessed pixel data and the calculated exposure value (EV).

8. TRADEMARK AND COPYRIGHT

Trademarks

Windows is a registered trademark of Microsoft Corp., Matlab is a registered trademark of Mathworks Corp.

Software by Third Parties

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dcoffin@cybercom.net
(http://www.cybercom.net/~dcoffin/dcraw/)

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