Photographic imaging instructions

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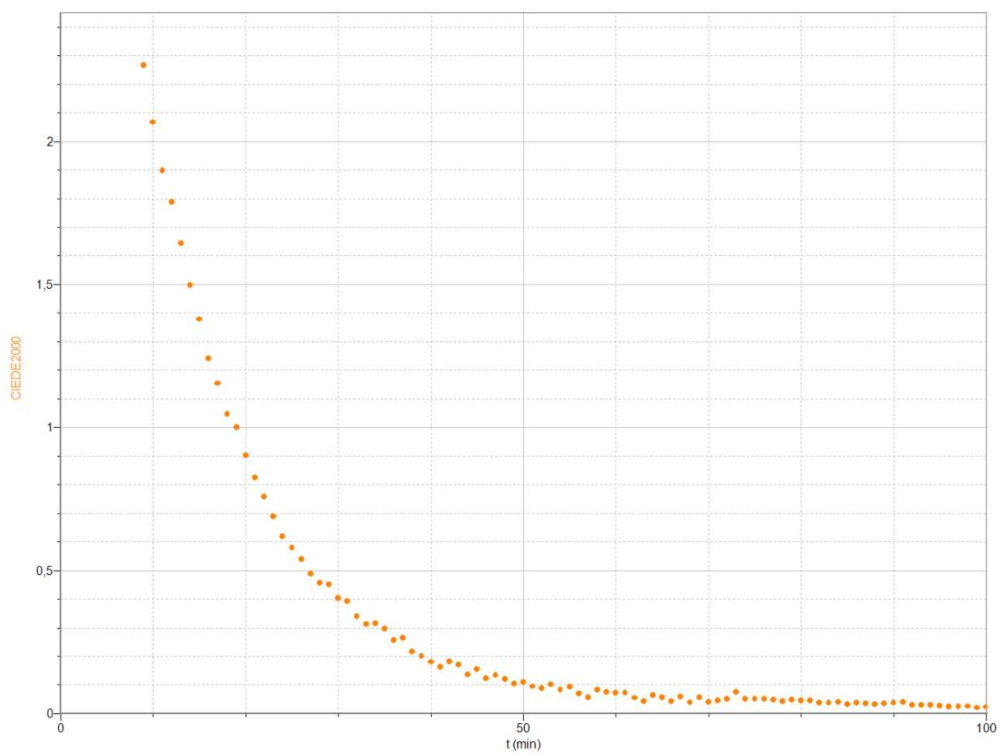
Imaging instructions

1. Turn on the LED panels

Make sure both panels are set to 100 % and 5500 K. Press dial to toggle between adjusting power and color temperature.

For accurate color data, wait for at least 30 minutes before starting measurements, or 50 minutes for the most accurate colors.

The graph below shows the approximate color difference for a gray card as a function of time since turning on the LED panels. The issue with beginning measurements right away is the colors will shift between the first sample and the reference gray card, thus resulting in incorrect colors. However, when the measurements only take a short time, the difference may be negligible. Generally, if the difference in CIEDE2000 in the graph is below 0.3 in the measuring time frame, the error will be negligible.



2. Turn on the camera

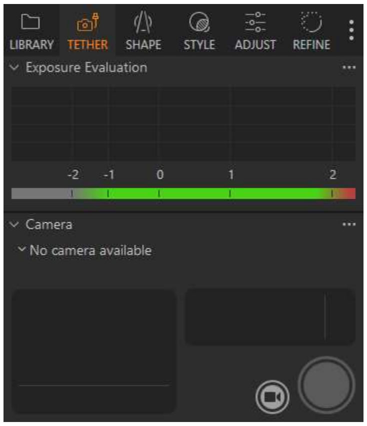
If the imaging surface has a lot of dust or smudges, it is a good idea to wipe it with a microfiber cloth before use, with some cleaning fluid if necessary. The same goes for the samples. For light dust, blowing it off with the blowing tool is enough. After some time, dust may also accumulate on the camera lens.

Take off the lens cap and place it on a clean surface to avoid getting dust on the lens.

It is good practice to also wait for a few minutes for the camera sensor to warm up, thus avoiding any (unlikely) color shifts.

Also make sure the camera is set to manual focusing mode (set by moving focus ring on lens up) by testing if the focus distance values on the lens move when rotating the focus ring.

3. Open Capture One



Press Tether in the menu in the upper left corner (which will be referred to as the **tool menu** from now on).

If the camera isn't recognized by Capture One, as in the image on the right ("No camera available"), make sure the USB-C cable is connected to both the camera and the computer, and restart the camera. After a camera restart, the focus must be set again.

4. Adjust camera height (to fit samples in frame when in focus)

After adjusting the camera height, focus the sample.

When adjusting focus by rotating the lens focus ring, the camera will display a zoomed-in version of the image. To return to the regular view, press the button next to G on the side of the lens.

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Refer to the tables below to select imaging height for the highest possible color accuracy. Selecting a focus height far from the 5 given options can result in additional dE of up to approx. 1.5. If resolution (refer to resolution table below) is more important than color accuracy, set the lowest possible focus distance and move camera down until the sample is in focus.

Focus height = camera height (highest visible line on scale under camera)

- sample thickness (distance from surface to area in focus)

Best focus heights for color accuracy

Focus height (cm)	38,7	41,6	45,6	54,0	64,5

Resolution by focus height

Focus height (cm)	38,7	41,6	45,6	54,0	64,5
Resolution (µm/px)	4,44	6,43	8,86	13,28	18,76

Because of vignetting (the corners of an image being darker than the center), it is best to leave around 15 % of space on both sides and 10 % at the top and bottom of the image where colors aren't of interest. This also avoids some chromatic aberrations and distortions at the edges of the frame and makes cropping images easier. These effects are especially noticeable at close focusing distances.

5. Focus the first sample

For accurate colors, it is very important to move into focus in the direction of increasing distance (the direction of the red arrow in figure on the right)! When you overshoot focus, move the focus ring back by at least 20° to a shorter focus distance and carefully try again. If the focus is set in the opposite direction, the image brightness will generally increase, causing the measured colors to become over-saturated, resulting in additional dE of up to approx. 6.

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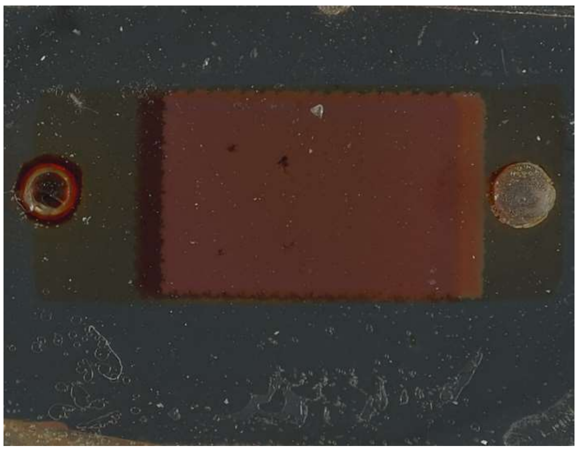
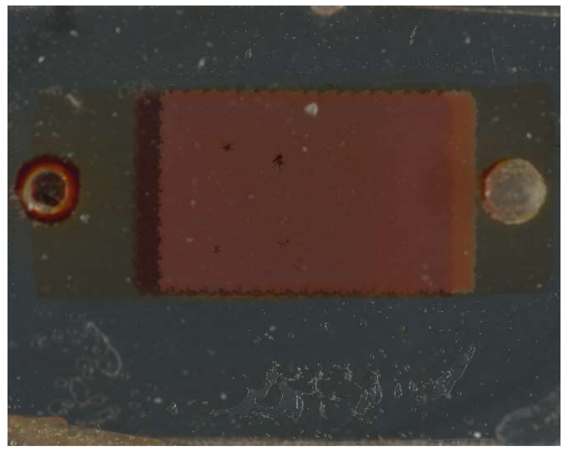
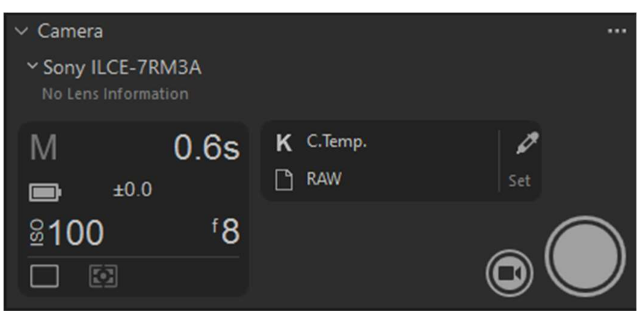
To assist in focusing, the camera will highlight areas of high contrast, which are in focus, in red. This is especially useful if the samples have small particles or sharp edges. If no highlighting occurs, find focus manually by adjusting until the desired part of sample is at its sharpest.

For shallower focus, move the camera closer to the sample, and vice versa. The benefit of deep focus is increased sharpness of a sample with varying thickness or multiple layers (image on the left). Shallower focus, on the other hand, separates the depth of interest from other layers (image on the right.).

6. Set correct exposure settings for selected focus height

The exposure settings can be adjusted by clicking on the setting's current value in the menu below. For future reference, the circle in the lower right corner is the button used for capturing an image.



An ISO of 100, aperture of f/8, the color temperature C.Temp., and image quality RAW should always be used. For the correct exposure time, refer to the table below.

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Exposure ranges

Focus height (cm)	-> 40,0	40,1 – 43,5	43,6 – 48,5	48,6 – 61,5	61,6 ->
Shutter speed	0.6 s	0.5 s	0.4 s	1/3	1/4

Next, scroll down to the menu section “Next Capture Adjustments” and select the options in the table below.

ICC Profile	Default
Orientation	180°
Metadata	Defaults
All Other	Defaults

Styles -> Custom Presets ->

Base Characteristics	Sony A7R3
Lens Correction	Sony A7R3
White Balance	Sony A7R3

ICC Profile, Metadata and All Other to Defaults. In Styles -> Custom Presets -> Base Characteristics, Lens Correction, and White Balance set each to Sony A7R3. If these are missing, refer to the software setup instructions (Download and install Capture One).

7. When LED panels are ready, image each sample

It is recommended to create a new album in the tool menu for each sample series in Library -> User Collections. Before imaging, select the proper album for images by right clicking on it and selecting Set As Capture Collection.

Focus the sample and close the imaging system’s door before capturing each image. Sometimes you may have to wait a moment for the sample to stop shaking from the impact of closing the door.

After the samples, image ColorChecker gray card without adjusting focus or any other settings. It is also best to image the samples in the same order each time to ensure the gray card is imaged with the same focus every time.

If each sample is of the same thickness, there is no need to adjust focus between images.

For automated interval imaging (timelapses), close Capture One and move to Imaging Edge Remote and capture images using software control, then import the resulting images into Capture One and continue like normal.

8. Make sure the images are using the correct settings

In Capture One, select one of the images and make sure in the tool menu in Style, the following settings are enabled.

Styles and Presets -> Custom Presets

Base Characteristics	Sony A7R3
Lens Correction	Sony A7R3
White Balance	Sony A7R3

9. Rename and export the images

The images must be named in the following format: "X-X_Z"

E.g. "seriesname-samplename_measurement", where X is the same for each sample, Y is different for each sample (and e.g. different part of a sample), and Z is a number that is same for each image taken at the same time. For easier time series plotting, the measurement number can also be based on hours, days, etc. from fabrication.

The reference gray card must be named as "X-gray_Z" for automatic detection.

Image names should not contain spaces or periods, or extra hyphens or underscores, to avoid errors in the automated color correction software.

Example names for a series named 220805a: "220805a-aronia1a_13", "220805a-1a_13", "220805a-gray_13".′

Export the images by selecting them, pressing the Export button in the upper left corner, and then Export x Images in the lower right corner of the popup window.

10. Run the python script through run.bat

Refer to the software setup instructions for running the script for the first time.

Select the script mode "Apply corrections".

Crop reference gray image as instructed at the top of the window, only leaving the gray area visible. It is recommended to use the safety margins when prompted. For no rotation or crop, press the space bar instead of enter. If you receive a warning for high reference gray dE, it is a good idea to check proper settings have been used. With optimal settings, the dE should stay below 1, and values over 2 are a strong indication something has gone wrong in the imaging process.

11. Crop the corrected images

Crop the images as instructed at the top of the window. For no rotation or crop, press the space bar instead of enter. To skip a sample, press escape.

When selecting reference points, it is recommended to select points as far apart as possible, in corners or other highly visible points on the samples.

12. Check the resulting images and copy them to another directory

The resulting images will be located in Images -> Corrected Images -> seriesname -> seriesname-samplename. For the cropped images, go to the Cropped sub-folder.

When you’re finished with a given sample series, delete the files from the corrected images directory. The copied files can be freely renamed. For taking measurements in the software, the file names must remain in the output format.

Python script instructions

1. Applying corrections

Refer to imaging instructions.

2. Creating calibration profiles

To create a calibration profile, first select the type of color target used, either "colorchecker" or "it87". The default option "it87" will be selected if left empty. Next, enter the focus height used (the target image should be in the Calibration Images folder, named "calib_focusheight.tif", with the gray card image named as "calib-gray_focusheight.tif"). Use reference gray safety margins (unless you know why you're not going to) and crop so that only the gray area is visible.

Select the shown reference points on the target image and press enter.

The script will first show an image with black lines showing original color deviation from reference colors shown as white points, and the title of the plot reading the average dE and the maximum dE in brackets. Then the image will be used to generate a correction LUT (which may take a minute or two) and then plot the LUT. Finally, a similar image to the first one will be printed with the corrections applied.

The resulting target image will be shown on screen. This should look similar to the actual target under the LED lights (assuming the computer monitor has OK calibration) with the most saturated colors being slightly duller as the image is shown in sRGB. If the rectangles don't match with the color sample squares, you will have to adjust the reference points or adjust the target image until they do. If the color samples still seem wrong, for example having random dark dots or other similar artefacts, the correction epsilon should be lowered in settings.py.

After pressing enter, the images will be closed, and the correction profile saved.

3. Measuring image uniformity

Using safety margins is recommended for checking the area of highest accuracy. To check the effect of vignetting, don't use safety margins.

Enter the name of the image to measure and crop to the area you are interested in measuring. For full image, press space.

The resulting image will show dE values of areas of the image compared to the average color of the image, where blue means points with lower L coordinate values (darker), and red means higher L coordinate values (brighter). Each integer increase in RGB coordinates (0-255) indicates 0.01 dE, and therefore the brightest possible pixels at 255 indicate a dE of 2.55 (adjustable in settings.py) or above, while black pixels indicate the area of image that matches the average color.

Some dE values and the average color of the measured area are printed in the terminal. Press enter to close the images, after which the uniformity image will be saved in Calibration -> Image Uniformity

4. Cropping images

Select the sample or series of samples you wish to crop, and whether you wish to adjust previously set cropping.

Crop the images as instructed at the top of the window. For no rotation or crop, press the space bar instead of enter. To skip a sample, press escape.

When selecting reference points, it is recommended to select points as far apart as possible, in corners or other highly visible points on the samples.

The cropped images will be located in Images -> Corrected Images -> seriesname -> seriesname-samplename -> Cropped.

5. Measuring series color data

Select whether you want to measure each pixel along a line or the average color of an area. For the selections, follow the instructions at the top of the window.

The measurement along a line generates a .csv file where the first line includes labels for each data column, and the following lines each include the data of a given measurement, separated into columns with commas. The data in each column is split by spaces into the data measured from a single point along the line. Therefore, the data is 3-dimensional.

The area measurement generates a similar .csv file, without space-separated data in columns. Therefore, the data is 2-dimensional.

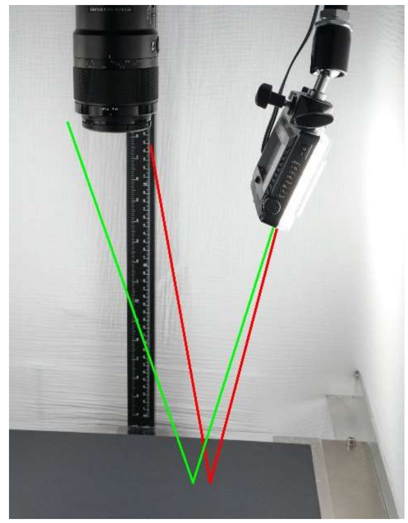
In addition to the .csv files with the measured data, compressed images showing the selection for each image will be saved in the measurement folder. (Images -> Corrected Images -> seriesname -> seriesname-samplename -> Measurements -> line/area-measurementname)

Calibration instructions

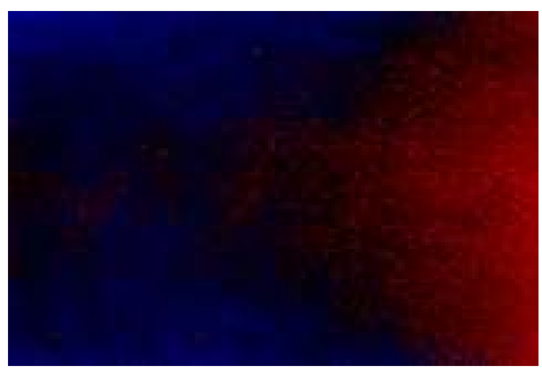
1. Illumination uniformity

For accurate color data, it is important to have an evenly lit imaging area. This can be achieved by adjusting the position and orientation of the LED panels.

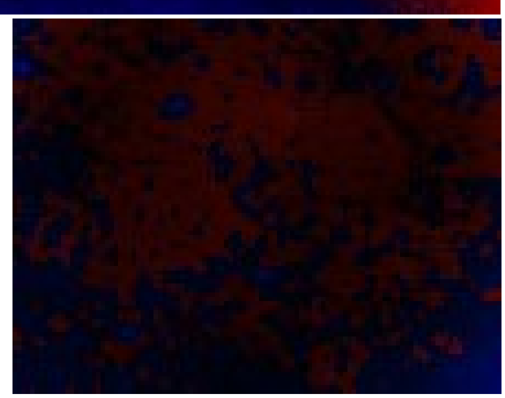
You can begin by using a regular light meter to get a roughly even illumination. It is also generally a good starting point to move the LED panels to the same depth as the camera so that they are centered, then move them as far away from the walls as possible without obstructing camera control, and finally raising them as high as possible without causing reflections into the camera, as illustrated in the image on the right. This is easiest to test by setting the camera to its maximum height and focusing on a reflective surface, such as a phone screen at the edge of the imaging area, and checking if you see reflections from the LED panels.



After this initial positioning, you can start using the image uniformity function in the Python script on images of a gray card to see which parts of the image are over and under-lit.



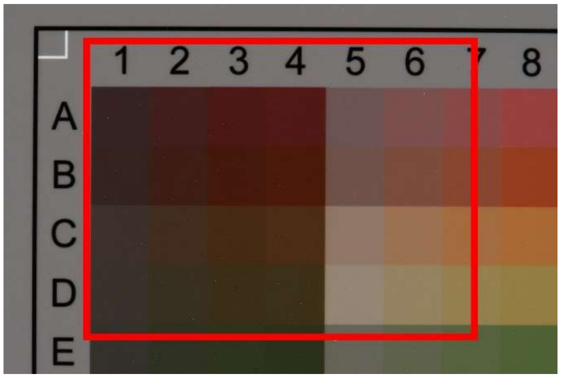
If the generated image looks like the one on the right, with the right side of the image clearly over-lit, you need to move the panels to compensate. To increase a panel's brightness, you can generally move it down or rotate it towards the surface. By moving a light closer to the wall, you will generally increase illumination at the edge of the image while decreasing illumination in the center. When the generated image looks like the one on the bottom, with a dim, random pattern of blue and red across the frame, you will have reached a uniform illumination. Color correction is required for proper dE values.



2. Color correction

After making sure your imaging area is illuminated uniformly, you can begin imaging calibration targets. For the most accurate color correction across a wide range of hues and saturations, using an IT 8.7 color target is recommended, as it includes far more color samples than a regular ColorChecker target, resulting in less interpolation and extrapolation. The downside of this is that IT 8.7 samples are generally less accurate as the samples are smaller and small errors have a larger effect on the resulting average color. This can be mitigated by combining images of multiple IT 8.7 targets to generate a target image with averaged colors.

To create a target image, capture images of the entire color sample area, avoiding the edges of the frame (sides: 15%, top/bottom: 10%) with less accurate uniformity. You can see an example of a target image with the safe area marked in red. Target images should be captured at one of the optimal focus heights for the widest dynamic range possible. Currently the convention is to use 540 mm as the target height. After the target images, capture an image of the ColorChecker gray card without adjusting any settings.



After capturing all the required images, combine them in e.g. Photoshop by expanding the canvas to fit all images and matching the sample areas to generate a single image in the shape of the original target. It is important to match the rotation and position of images so the samples will be picked correctly by the correction script. After combining the images on separate layers, remove the edges of each image for accurate colors while maintaining some overlap between samples to avoid showing the background color. Finally, flatten the image and resize to less than 40 megapixels to avoid generating an unnecessarily large correction image. 10 megapixels is plenty for measuring the samples' average colors. Make sure to save the image in the original format without compression or color space transformations. This should happen automatically if you save the file as is, on top of the first image.

When you have a finished target image, you can follow the calibration steps in the Python script instructions.

Software setup instructions

1. Python

If Python isn't already installed on the system, go to python.org/downloads and download the recommended version. Run the installer and select Add Python to PATH.

Simultaneously press Windows button + R, type in "cmd" and press enter. Run the following commands:

- pip install colour-science
- pip install matplotlib
- pip install opencv-python
- pip install natsort
- pip install PyExifTool

Copy script files into a "Python" folder under a main imaging directory. Running the program will automatically generate the rest of the required file structure.

Download the ExifTool Windows Executable from exiftool.org and extract (and rename if necessary) the exiftool.exe file into the Python folder.

Create the folder "ICC Profiles" inside the Python folder and download at least the following profiles (and rename to match the name) into the folder.

- sRGB.icc (color.org/srgbprofiles.xalter -> sRGB_v4_ICC_preference.icc)
- Adobe.icc (adobe.com/support/downloads/iccprofiles/icc_eula_win_end.html -> Accept, Extract RGB -> AdobeRGB1998.icc)
- ProPhoto.icc (sites.google.com/site/chromasoft/icmprofiles -> ICCProfiles.zip, extract ProPhoto.icc)

Also copy the ICC Profiles into C:\Windows\System32\spool\drivers\color for use in other applications, such as Capture One and Adobe Photoshop.

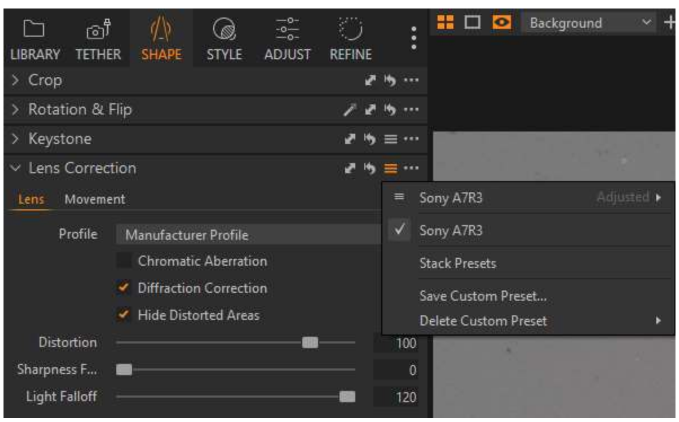
2. Download and install Capture One

After installation, connect the camera to the computer with the USB-C cable, go to Tether in the tool menu (shown in step 3 of imaging instructions).

In Camera Settings, select the White Balance setting C.Temp., Quality RAW, Image Size L, Aspect Ratio 3:2, Drive Mode Single Shot, and DRO OFF. Scroll down to White Balance and set to 5500. Below Camera Settings, in Next Capture Naming, set a desired format and name for images, for example the existing default options. In Next Capture Location, select the Remote Capture folder created by the Python script and Capture Collection.

Now capture a test image using the default exposure settings by clicking on the circle capture button, or the Capture button in the upper left corner of Capture One and select the image that appears in Capture One.

Now go to Shape in the tool menu, and select the options shown in the image below, click on the three bars and Save Custom Preset from the drop-down menu, check all boxes and save the preset as Sony A7R3.copreset.

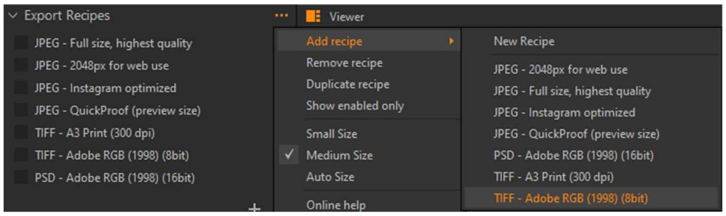


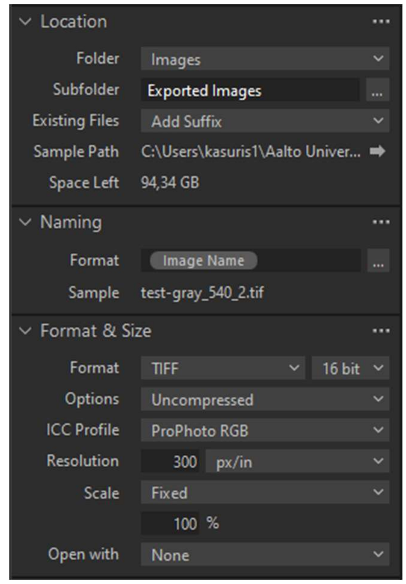
Click on the three bars again and select the created Sony A7R3 preset. Now click on the three dots on the right side of the bars and select Save as Defaults for Sony A7RM3.

Go to Style in the tool menu. In Base Characteristics, select Show All in ICC Profile, then Effects -> No color correction. In Curve, select Linear Response. Save the preset, select it, and save as default, same as before.

Go to Adjust in the tool menu. In White Balance, set Kelvin to 5500 and Tint to -3, and save the preset select it, and save as default, same as before.

Finally, click Export in the upper left corner, and select the following option after clicking the three dots. The Images and Exported Images folders are created by running the Python script for the first time.





After selecting all the options, double click on the created recipe, name it as Export, select the recipe, and export the test image, which can then be deleted from Capture One and the computer.

You can delete all other export recipes in the export menu.