Photographic imaging instructions

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August, 2022 (Rev. June, 2023)

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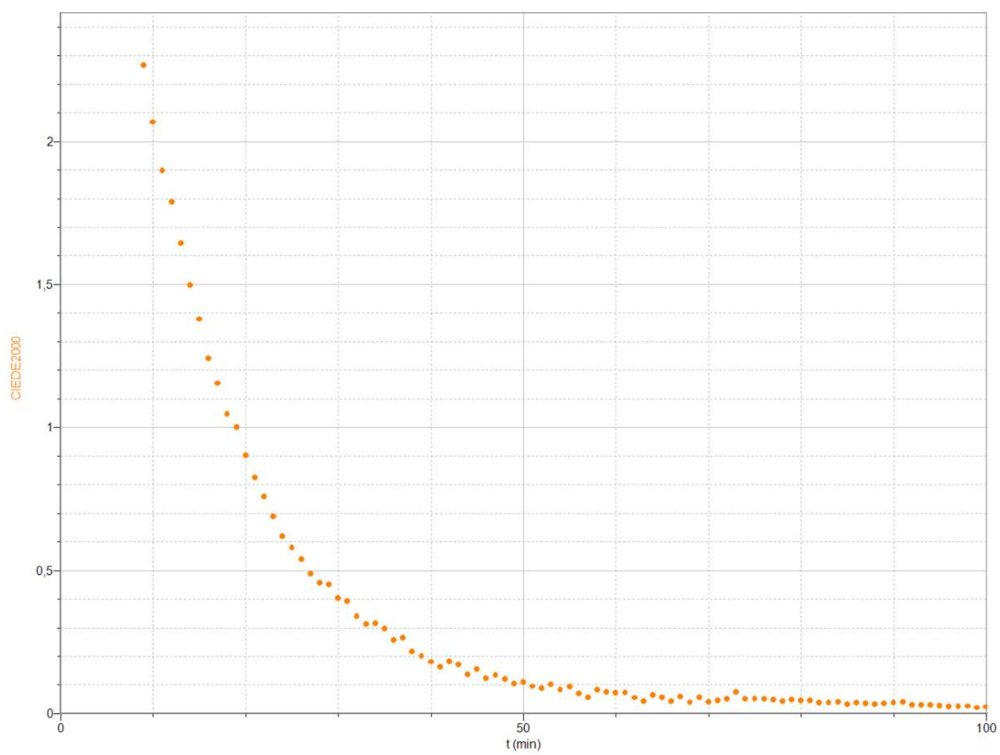
Imaging instructions

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. Open Capture One

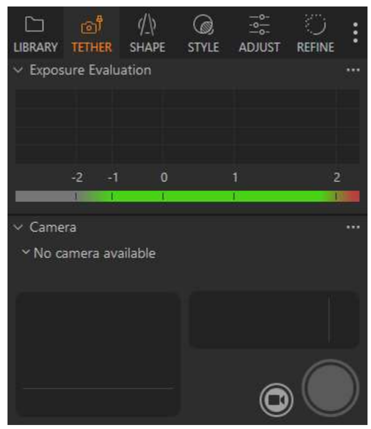
Press Tether in the menu in the upper left corner (which will be referred to as the **tool menu** from now on).

3. 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 electronic focusing mode (set by moving focus ring on lens down) by testing if pressing '-' on the remote makes the view on the camera screen zoomed in.

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.

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 the '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)	39,0	42,0	46,0	54,0	64,5

Resolution by focus height

Focus height (cm)	39,0	42,0	46,0	54,0	64,5
Resolution (µm/px)	4,78	6,81	9,15	13,4	18,7

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. With the Python script's default settings, the safety margins will be automatically cropped out.

5. Focus the first sample

Rotate the lens ring by hand to get a starting point for focus and make fine adjustments using the '+' and '-' buttons on the remote. When focus is set, press '-' 5 times and then '+' 5 times on the remote. Without this step, if the focus is set in the direction decreasing the focus distance, the image brightness will generally increase, causing the measured colors to become over-saturated, resulting in additional dE of up to approx. 6. The same usually happens if the step is not performed after each camera restart.

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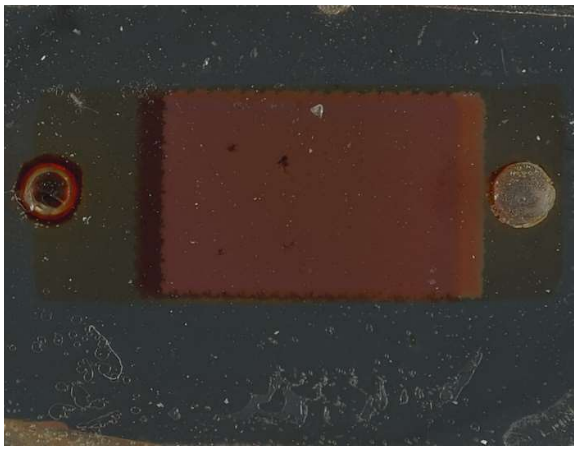
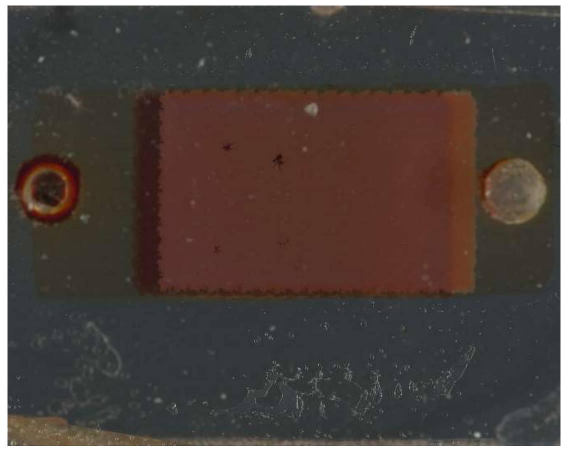
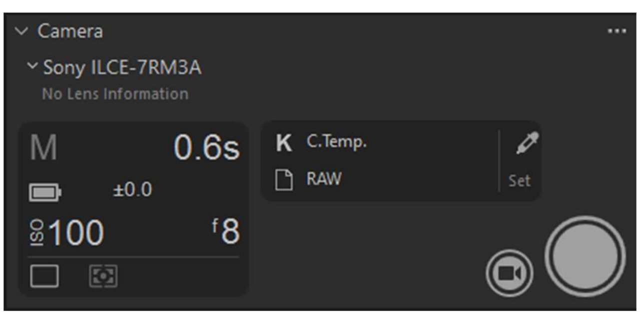
To assist in focusing, the camera will highlight areas of high contrast, which are in focus, in red. This is especially useful if the samples have small particles or sharp edges. If no highlighting occurs, find focus manually by adjusting until the desired part of sample is at its sharpest.

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 ->
Exposure time	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.

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For automated interval imaging (timelapses), change the Name in Tether -> Next Capture Naming to e.g. “timelapse-test_” and use the interval imaging device to capture images, following the Timelapse instructions. After imaging, continue steps like normal. Remember to change the Name back when done.

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-y_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 N 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”. (If images were captured as a timelapse with the IV carousel, first use the mode “Rename carousel timelapse files”)

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 if prompted. For no rotation or crop, click on the image to select the window and press Space 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 1.5, and values over 2.5 are a strong indication something has gone wrong in the imaging process. This may be as simple as holding the imaging system’s door open for too long, letting the LED panels cool down.

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.

If you will not be imaging a sample series again, delete the files from the corrected images directory. The copied files can be freely renamed. For taking measurements in the software, the file names and folder structure must remain in the output format.

Python script instructions

1. Applying corrections

Refer to imaging instructions.

2. Cropping images

Select the sample (e.g. “230613-7”) or series of samples (e.g. “230613”) 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. If images were captured as a timelapse, press A before pressing enter.

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

3. Measuring series color data

Select whether you want to measure each pixel along a line or the average color of an area, and the series of samples e.g. “230613-1”. 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 each 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.

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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)

4. Measuring image uniformity

For producing the images required, refer to ‘Illumination uniformity’ under ‘Calibration instructions’

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

5. Creating calibration profiles

For producing the images required, refer to ‘Color correction’ under ‘Calibration instructions’

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-targettype_focusheight_N.tif”, with the gray card image named as “calib-gray_focusheight.tif”). Use reference gray safety margins if asked (unless you know why you’re not going to) and crop so that only the gray area is visible.

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Select reference points on the target images 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 reference target will be shown 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.

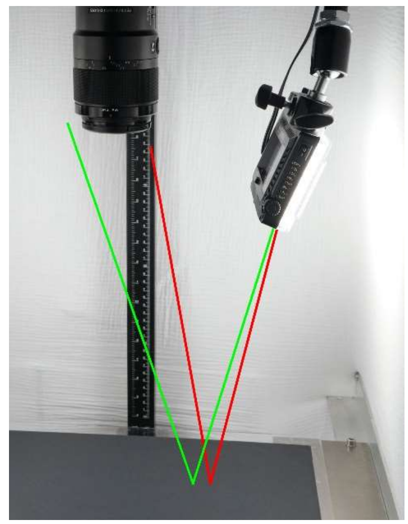
After pressing enter, the images will be closed, and the correction profile saved.

Calibration instructions

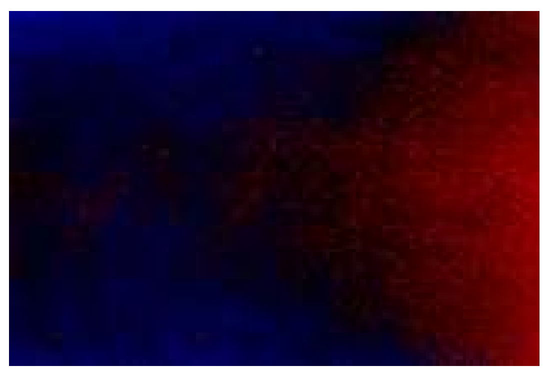
1. Illumination uniformity

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.

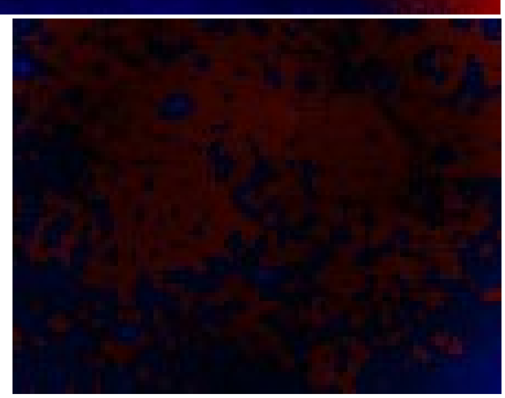
You can begin by using a regular light meter to get a roughly even illumination. It is also generally a good starting point to move the LED panels to the same depth as the camera so that they are centered, then move them as far away from the walls as possible without obstructing camera control, and finally 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.



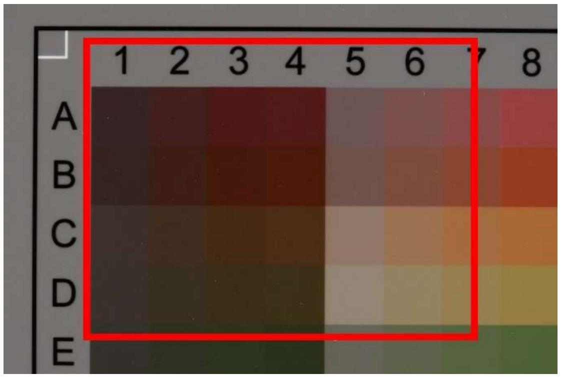
If the generated image looks like the one on the right, with the right side of the image clearly over-lit, you need to move the panels to compensate. To increase a panel's brightness, you can generally move it down or rotate it towards the surface. By moving a light closer to the wall, you will generally 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, export them, and move the exported images, without applying corrections, to Images/Calibration/Calibration Images.

Follow the calibration steps in the Python script instructions.

Timelapse instructions

1. Timelapse of single sample without IV curves

A separate process is yet to be implemented. As a workaround, follow the process for multiple samples, but instead of using the IV curve carousel, just place your sample and the gray card on the regular imaging surface, set the number of samples in Autolab software to 1, and delete the 'IV Curve' procedure group under 'Repeat every 1 hour' and 'Cells 1-8'. Make sure the IV curve carousel can move, as it will still rotate between positions 1 and 2.

2. Timelapse with multiple samples, Autolab IV curves

Start by following the regular 'Imaging instructions', until told to refer to this section in step 7.

Attach the samples to the IV curve carousel, remove the glass imaging surface and background cardboard from the imaging system, and place the carousel inside. The carousel surface is 2,1 cm below the regular imaging surface.

Make sure the Arduino has 2 orange LEDs on. If not, plug in the power supply.

Make sure the imaging carousel surface is rotated all the way counterclockwise and is touching the stopper on the bottom of the disc. Position the imaging carousel so that the first sample and the gray card are visible on the camera screen, not too close to the edges of the frame.

Turn on the Autolab device by pressing the button in the upper left corner, after which the button should light up. Open Nova and select Import procedure on the home screen. Select IV_curves.nox from the Autolab\Procedures folder. In the opened procedure tab, click on "Repeat every N minutes" and in the Properties window on the right, set the interval time between imaging the samples. In the duration, set a multiple of the selected interval time so the number of repetitions is as desired. To set the number of cells to image, click on "Cells 1-8" and More in the Properties window. Click on each Cell value above number of cells to image and press delete.

Make sure the Autolab folder doesn't contain any "iv_curve..." files and begin the timelapse by pressing F5.

After finishing the timelapse, continue following the regular Imaging instructions.

Software setup instructions

1. Python

If Python isn't already installed on the system, go to python.org/downloads and download Python 3.10. Run the installer and select Add Python to PATH.

Copy script files from github.com/severikasurinen/photographic-imaging into a "Python" folder under a main imaging directory. Run install.bat.

Download the ExifTool Windows Executable from exiftool.org and extract 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.

Change options in settings.py as required, keeping in mind that changing settings related to image processing may result in incorrect processing. The most important settings to check are the max_window, output_illuminant, output_color_space, output_depth, output_extension, main_directory, and system_memory.

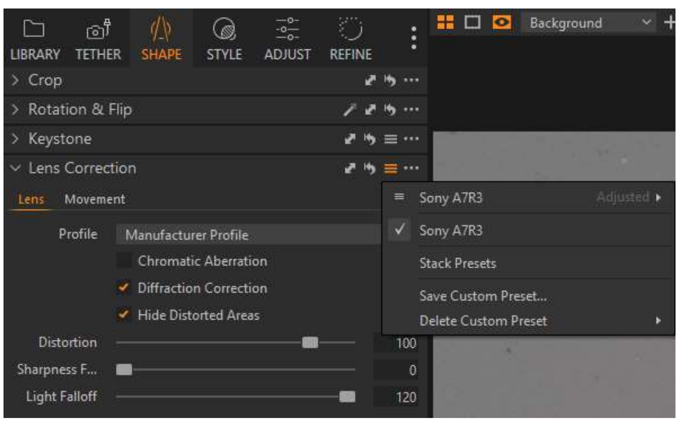
2. Download and install Capture One

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 (e.g. Name, Camera Counter) and Name (e.g. "imaging-2023_") for images. 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.

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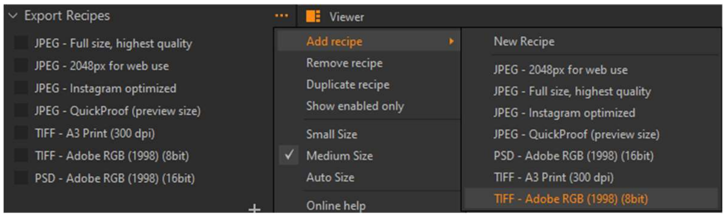
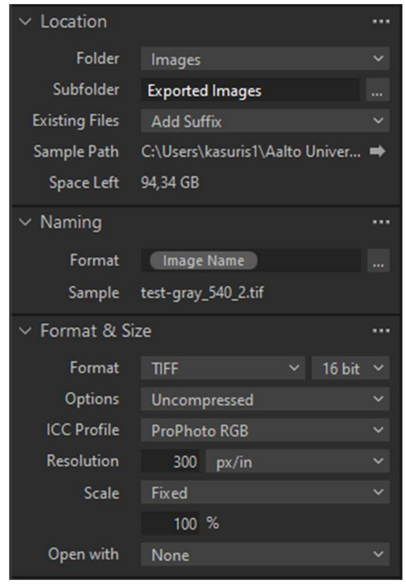
Finally, click Export in the upper left corner, and select the following option after clicking the three dots. The Images and Exported Images folders are created by running the Python script for the first time.





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.