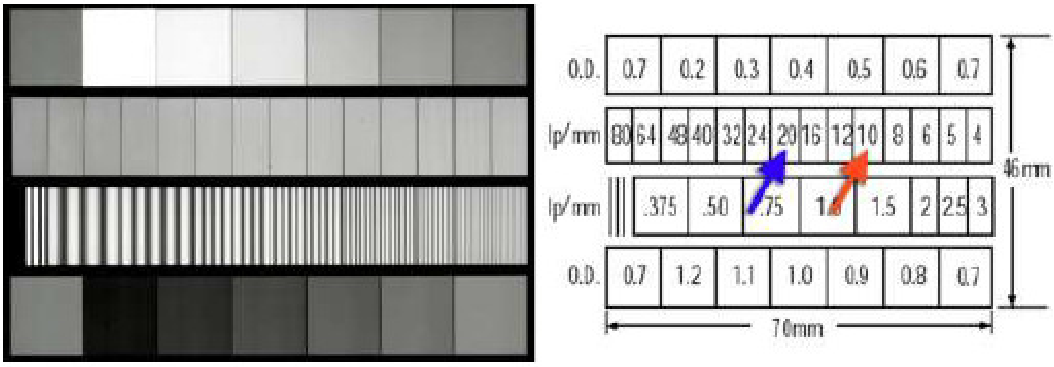
Centre de Recerca i Difusió de la Imatge

Ajuntament de Girona

REPORT ON THE CHARACTERISATION OF THE CRDI EQUIPMENT FOR DIGITISATION



Test target employed for the system aliasing response measurement.

Test target suited for the system MTF measurement.

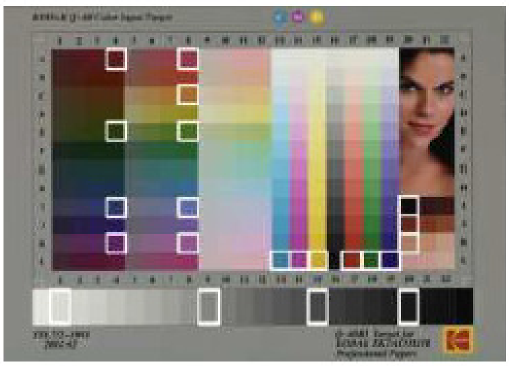


Image test of the IT8.7/2 colour chart. (with measured patches indicated)

Date:	**September 2012**
Institution :	**Centre de Recerca I Difusió de la Imatge (CRDI) – Ajuntament de Girona**
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Device Characterisation and Recommended Procedures

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1. Scope and Contents

This report aims to help in the work of reproduction at CRDI facilities. This work is targeted both on the reflective and transmissive original photographic materials that must be reproduced from a zenithal point of view. The ensemble of materials includes photographic prints, imprinted cards, flexible films and glass plates in both positive and negative form.

The second section, ***Instrument Data***, details the camera and lens specifications.

The third section, ***Lens Characterisation***, states the lens properties that can affect the final image quality.

Section fourth, ***System MTF Measurement***, is dedicated to the system MTF measurement under different work conditions.

The fifth section, ***System Aliasing Effects Measurement***, analyses the system response to a signal higher than the system Nyquist frequency.

The sixth section, ***System OECF Measurement***, states the system response to incremental light impulses and measures its dynamic range (DR).

Seventh section, ***Colour Management***, shows the colour calibrations performed for the different camera configurations and the items to be reproduced characteristics.

The eighth section, ***Conclusions and Recommendations***, proposes a series of device adjustments derived from the respective MTF, ESF, OECF, Aliasing and Colour Management results, along with some recommendations about work procedures.

Ninth section, ***References***, lists the references about measures and methods employed.

2. Instrument Data

2.1. Camera and Lens

The device target of this work is a photographic camera with the following specifications:

- Camera body: ***PhaseOne 645DF*** Serial Nº *PJ005232*.
- Digital back: ***PhaseOne P40+*** Serial Nº *EG031689*.
- Lens: ***PhaseOne 120mm AF Macro f/4*** Serial Nº *PR001283*.

The camera body *PhaseOne 645DF* is a single lens reflex body (SLR) equipped with a focal plane shutter; the body admits interchangeable lens and digital backs. The camera can also be equipped with between the lens shutter lenses, which allows for electronic flash synchronization with shorter exposure times.

The unit object of this characterisation equips a *PhaseOne 120mm AF Macro f/4* lens with an aperture range from *f/4* to *f/32*. Along with the *645DF* body configures an autofocus (AF) system based on phase detection. This cancellable automatic system indicates the correct adjustment in the viewfinder.

The digital back employed is the *P40+* from thee *PhaseOne* range. This back equips a CCD sensor of *32.9x43.9mm* and *5484x7320 photo-receivers*, with a pitch of *0.006mm* (*6microns*). The back can also be used with a *2742x3660 photo-receivers* in the so called *Sensor+* configuration; this configuration avoids the colour interpolation at the demosaicing level. The photo-receivers size in the *Sensor+* mode is of *0.012mm* (*12microns*).

2.2. Lighting System

The lighting system employed for all the trials performed is the same that will be employed at the CRDI reproduction work. This is specially important to preserve because two basic reasons:

- The colour temperature and the constancy of the energy output both affecting the sensor response in terms of colour accuracy and Colour Mangement.
- Exposure time related with the energy output that influences too the sensor response, this time related with colour accuracy and noise.

For the opaque materials reproduction, the system consists in two electronic flash strobes Hensel Integra Plus Advanced 500, both equipped with silver standard reflector, light shades and filter holder. The translucent material will be illuminated by transmission with a rigid light box Hensel Boxlite of *30x50cm* connected to a Hensel generator.

3. Lens Characterisation

3.1. Test Target

As a previous measure to the lens-sensor system characterisation the image of a suited test target has been captured to characterize the possible residual aberrations present in the lens image (Figure 1). The test image has been captured at the *f/8* lens opening.

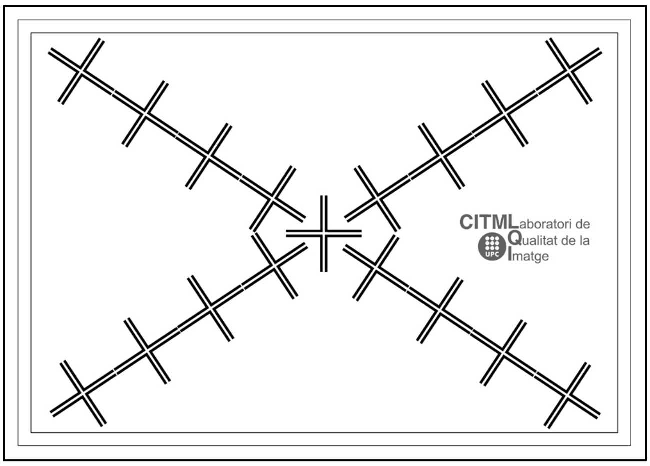
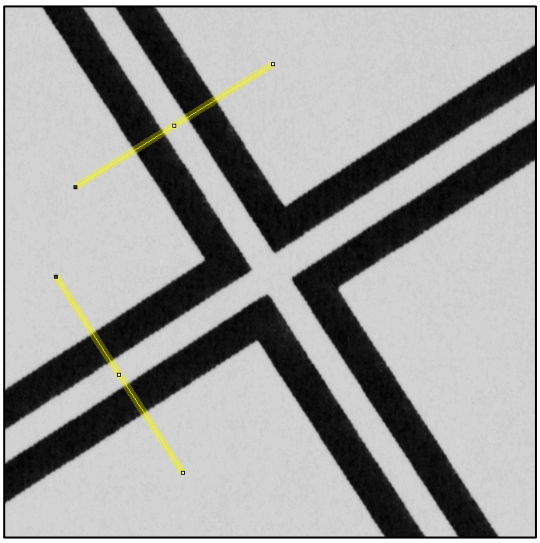


Figure 1 – Test target to characterize the different photographic lenses residual aberrations.

3.2. Results

After the test performed, those are the results obtained:

- Absence of significant distortion aberration effects.
- Absence of residual astigmatism (Figures 2 and 3).
- Absence of transverse chromatic aberration or TCA (Figure 2).
- Any significant difference of sharpness between the centre and the borders of the image field (Figure 4).
- The vignetting at the work distance is barely significant (Figure 4 and Table 1).



Figur2 2 – Magnified section of the image field corner from the test target image. Yellow selections indicate the pixel grey value measures performed in the sagittal and tangential directions.

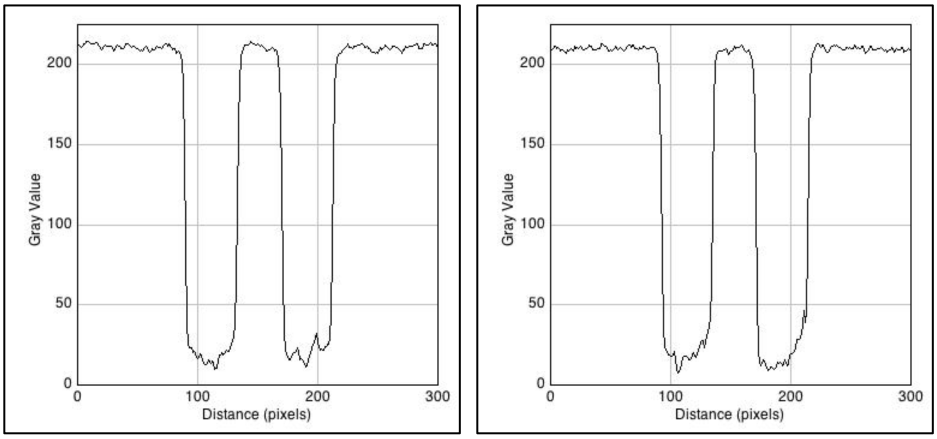


Figure 3 – Pixel value plots corresponding to the selections shown in the Figure 2. At left, sagittal direction measure; at right, tangential selection plot.

Astigmatism. The Figure 2 shows that both sagittal and tangential black bars present similar sharpness that is confirmed by the pixel grey value plots of the Figure 3; this similarity confirms the absence of astigmatism.

Transverse Chromatic Aberration (TCA). On the tangential bars of the same Figure 2 can be observed as the black to white edges do not show colour fringes, confirming the absence of transverse chromatic aberration or TCA.

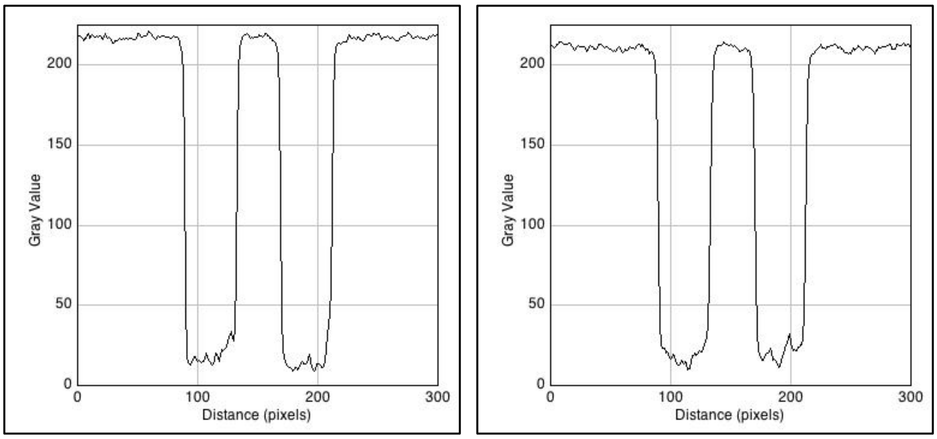


Figure 4 – Pixel grey value plots corresponding to the two pixel selections over the sagittal bars at respectively the centre (left) and the corner (right) of the image field.

Other Aberrations. The pixel grey value plots taken from the centre and the corner of the image field shown in the Figure 4, do not present any significant difference in sharpness. At the *f/8* lens opening and the work distance selected, can be hence discarded the presence of any other residual aberrations (spherical, coma, field curvature, longitudinal chromatic (LCA) or combinations of some of them) affecting the sharpness at the image field corners. The same result can be extrapolated to the smaller lens apertures from *f/11* to *f/32*. In the case of wider diaphragm apertures, *f/4* and *f/5.6*, can be expected to detect some residual aberrations effect on the captured images as is confirmed by the system MTF results (see the Results on the section *4. System MTF Measurement*).

Vignetting. Comparing the pixel grey value plots from the Figure 4 can be observed a little difference in value at the high light region of the test image, consequence of the lens vignetting at the image field corners. In order to quantify this effect, measures where taken of *200x200pix* selections over the centre and the four corners of the image field. The measurement results of its average grey value and the respective standard deviations can be seen at the Table 1.

Field position	average	standard deviation	minimum	maximum
centre	*218*	*2.0*	*207*	*227*
corners average	*205*	*2.0*	*192*	*213*

Table 1

As can be observed, the average difference is of only 13 grey values between the centre and the corner measurements. This difference has not significant value in the case of reproducing items of varied and randomly distributed tonal values over its surface. In the special cases of reproducing textual documents or items of smooth surface of the same or similar tone value, this vignetting can be fixed by digital image processing at post-production stage.

4. System MTF Measurement

4.1. Experimental Setup

The experimental setup employed for the system MTF measurement consists on the camera attached to a vertical reproduction stand at a work distance suited for the reproduction of flat opaque originals in the context of the CRDI workflow, resulting in a working magnification of *m = 0.15*. With this configuration, two series of slanted edge test target images where taken at all the diaphragm apertures available in the camera lens; the first series activating the Standard camera configuration mode and the second one selecting the Sensor+ mode.

In all cases the software controlling the camera back was adjusted with a linear luminance transition map and all adjustments related with edges enhancing and noise reduction where cancelled. From the files captured, the system MTF was measured bay means of the ImageJ plug in *SE_MTF_2xNyquist*.

4.2. Test Target

The etst target employed for the system MTF is shown at the Figure 5. The scheme allows for the system MTF measurement in both vertical and horizontal directions from the same image file; this simultaneous measure avoid the little differences that can be found between consecutive camera takings, even under the same conditions. The area full of text is used to point the camera AF selection mark, while the squared shape indicated with the *25mm* legend allows de determination of the actual working magnification from the image pixels measure. As is stated by references, the test target must be slightly slanted, in between *5º* and *10º*, referring to the camera sensor coordinates. This is done because of the absence of invariance properties in the discrete sensors.

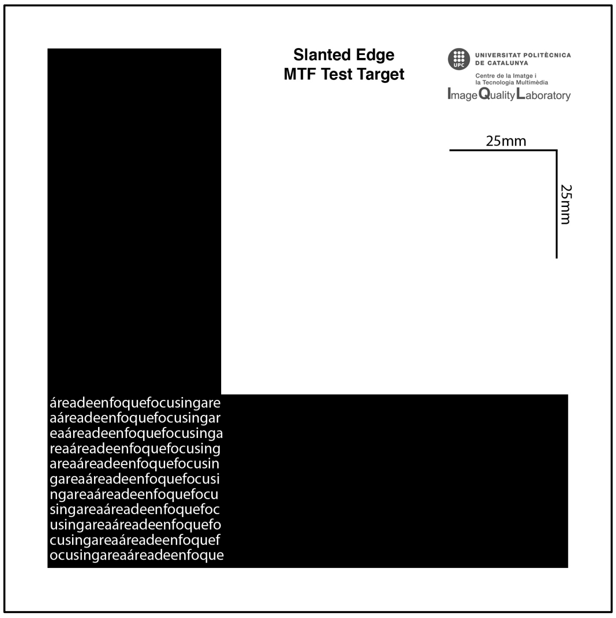


Figure 5 – Test target suited for the system MTF measurement. The "L" shaped allows for both horizontal and vertical measurements from the same image file. The text area serves as AF target and the 25mm corner can be used to calculate the actual working magnification.

4.3. Standard Configuration Mode Results

The Figure 6 shows the results for the system MTF measurement at the seven diaphragm apertures available in the employed lens with the digital back configured at the Standard mode.

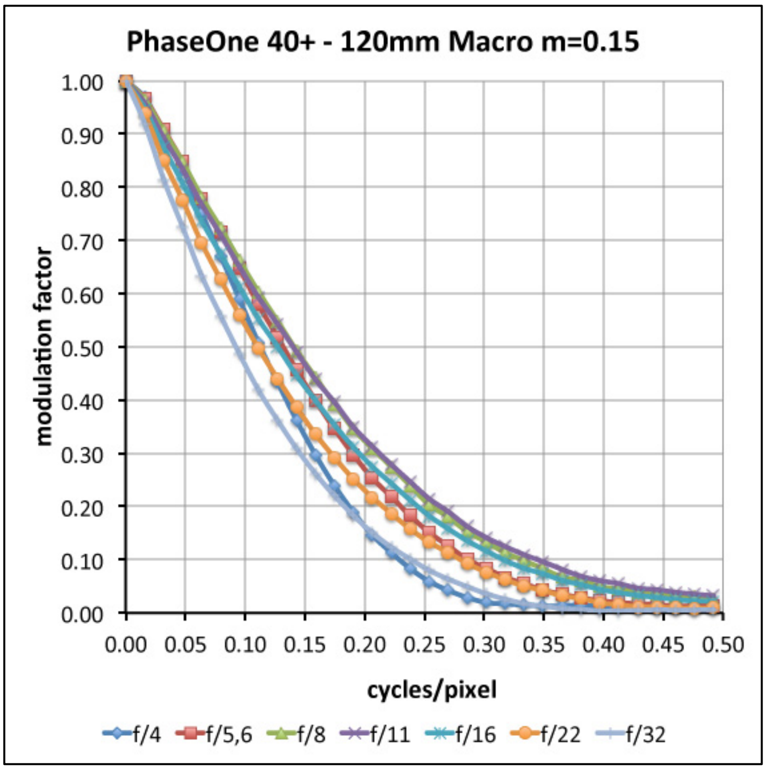


Figure 6 – Set of system MTF measured at the seven diaphragm apertures avalilable in the camera lens with the digital back configured with the Standard mode.

From those results can be derived the following conclusions:

- The *f/4* opening cannot be used to take pictures. The MTF curve fall down at zero modulation at *0.35cycles/pix* (aprox. ¾ of the sensor resolution limit). The most probable cause is the presence of some lens residual aberrations.
- The *f/32* aperture is so poor in performance as the previously discussed *f/4*. In this case, the cause of the low performance can be attributed to the diffraction combined with the photo-detectors size.
- The best system response can be found at the *f/8* and *f/11* openings followed very close by the *f/16*.
- The *f/5.6* and *f/22* apertures respective MTF show an intermediate performance value. The cause can be attributed to different agents; while some residual lens aberration effects can cause the *f/5.6* result, the *f/22* result shows the early diffraction image degradation.

4.4. Sensor+ Configuration Mode Results

The Figure 7 shows the results for the system MTF measurement at the seven diaphragm apertures available in the employed lens with the digital back configured at the Sensor+ mode.

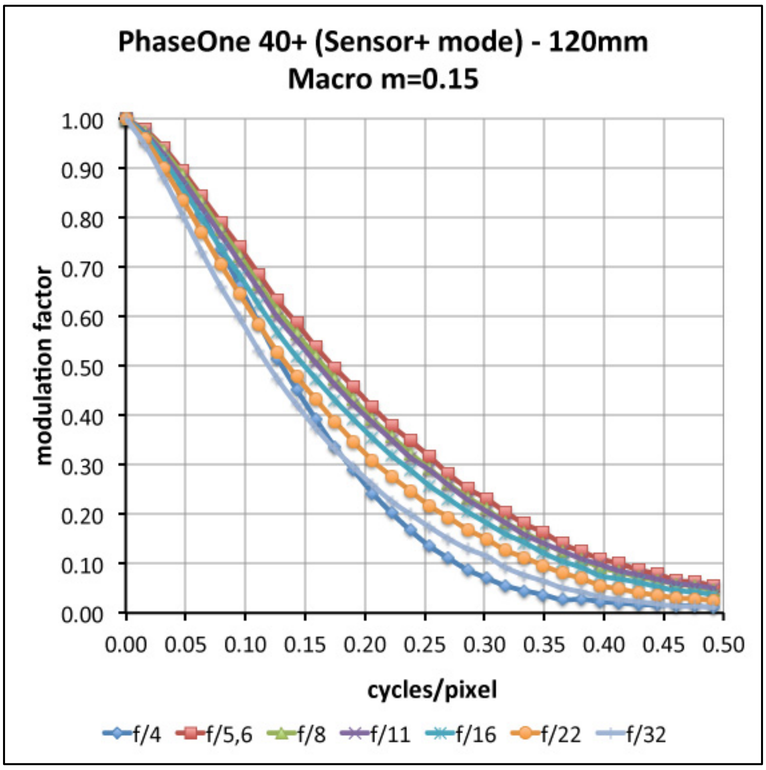


Figure 7 – Set of system MTF measured at the seven diaphragm apertures avalilable in the camera lens with the digital back configured with the Sensor+ mode.

The results can be resumed as:

- The lens openings *f/4* and *f/32* show the same low performance detected in the Standard mode back configuration, while the modulation factor fall down to zero value is found more close to the Nyquist frequency (aprox. at *80%* of the sensor resolution limit).
- The results for the majority of the resting lens apertures, from *f/5.6* to *f/16*, are very similar between them.
- The f/22 result shows an initial descent in performance probably attributable to the diffraction effects.
- Nevertheless, at the respective lens aperture settings, the results in performance of the system MTF in the Sensor+ configuration mode are always slightly better than those of the Standard mode configuration mode.

5. System Aliasing Effects Measurement

5.1. Sinusoidal Test Target

The measurement of the system false responses or aliasing was done by means of the analysis of a suitable sinusoidal test target captured images taken at the two back configuration modes, Standard and Sensor+. The corresponding measurements have been performed from series of images taken at the seven diaphragm apertures available at the lens. This is done in order to evaluate the lens resolving power influence in the sensor performance, because of the fact that, according to the manufacturer's data, the sensor do not equips any optical nor software low pas filter or anti-alias system.

The test target employed for the measures of the system response in terms of aliasing is the manufactured by Edmund Optics, which is shown in the Figure 8. The two central rows present a series of sinusoidal patterns of incremental frequency. The working magnification was adjusted at a suitable value that so that one of the test patterns is coincidental with the system Nyquist frequency. At the right portion of the Figure 8 are shown the respective frequencies; in blue the limiting frequency for the back Standard configuration mode and in red the corresponding to the Sensor+ mode.

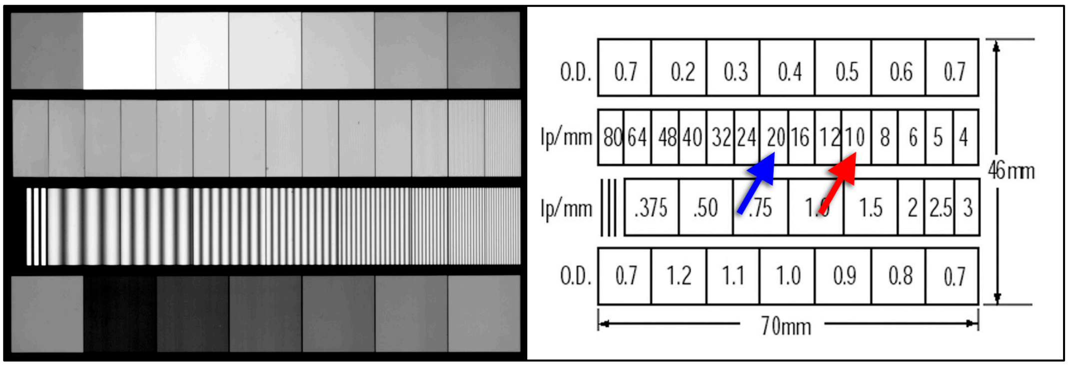


Figure 8 – At left, test target employed for the system aliasing response measurement. At right, test scheme indicating, at the central rows, the frequency of each sinusoidal pattern. The blue arrow indicates the limiting frequency for the back Standard configuration mode and the red one for the corresponding to the Sensor+ mode.

5.2. Results for the Standard Configuration Mode

At the Figure 9 can be appreciated the aliasing measures performed with the back at the Standard configuration mode.

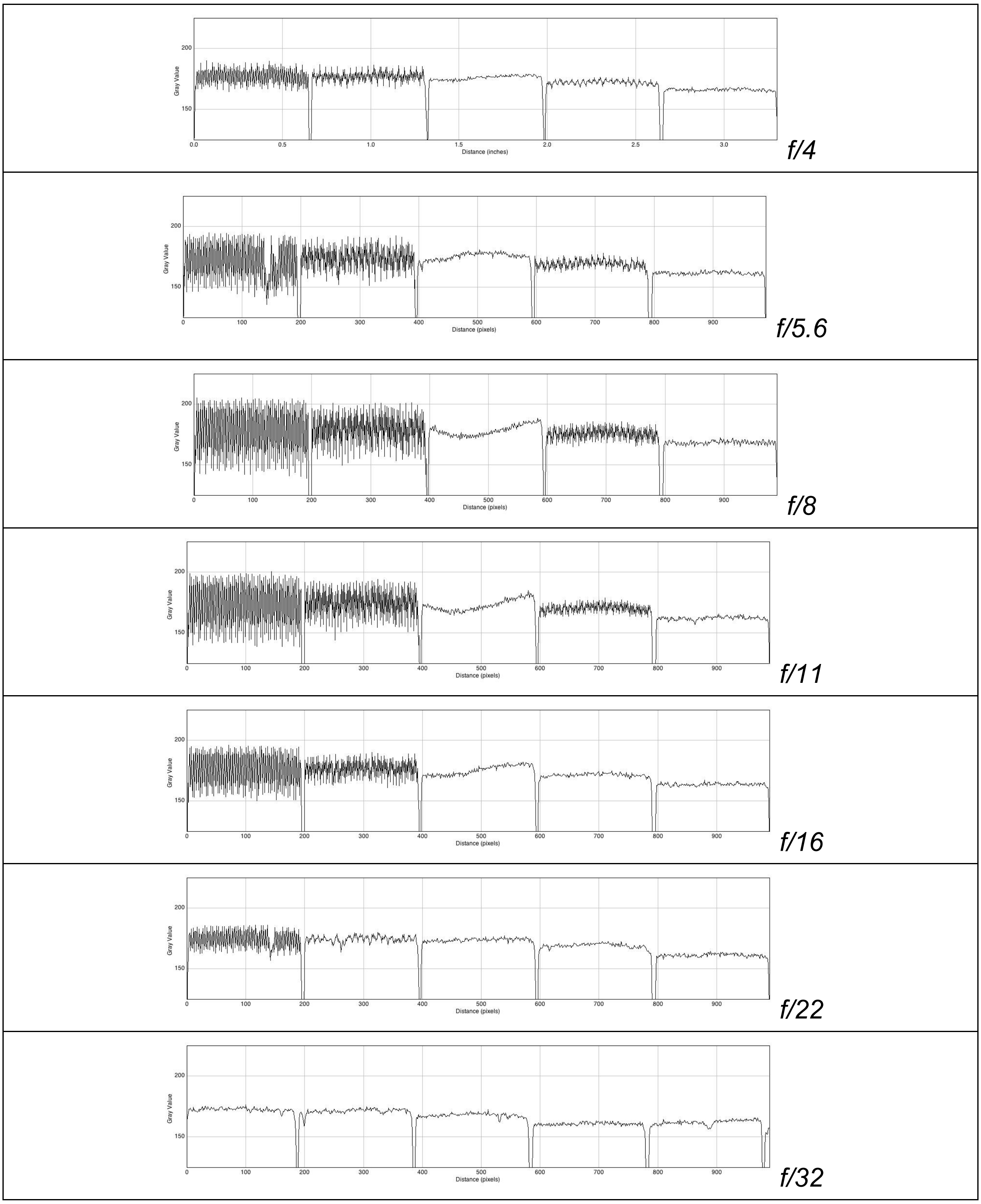


Figure 9 – Set of system responses in terms of aliasing corresponding to the seven lens apertures, with the back in the Standard mode. The pixel grey value plots show the response to five sinusoidal patterns where the central one corresponds with the system limiting frequency.

The plots show the pixel grey values of five patterns taken from the respective seven apertures images, where the central one corresponds with the system limiting frequency. This the last one that must be resolved by the system, while the couple at right side should not show any response in normal conditions. From the plots can be deducted the following:

- The system cannot resolve in any case the pattern containing its limiting frequency.
- The plot corresponding to the lens *f/4* opening shows an aliased response of low modulation.
- The false responses are more obvious at the *f/5.6*, *f/8* and *f/11* apertures.
- The plots corresponding to the apertures of *f/16*, *f/22* and *f/32* do not show any significant response beyond the Nyquist frequency.
- Working at the *f/5.6*, *f/8* and *f/11* apertures there is a risk of system false responses or aliasing if the object to be reproduced contains the respective frequencies. In the case of those frequencies presenting periodic patterns, the image can be affected by *moiré* patterns.

5.3. Results for the Sensor+ Configuration Mode

At the Figure 10 can be appreciated the aliasing measures performed with the back at the Sensor+ configuration mode.

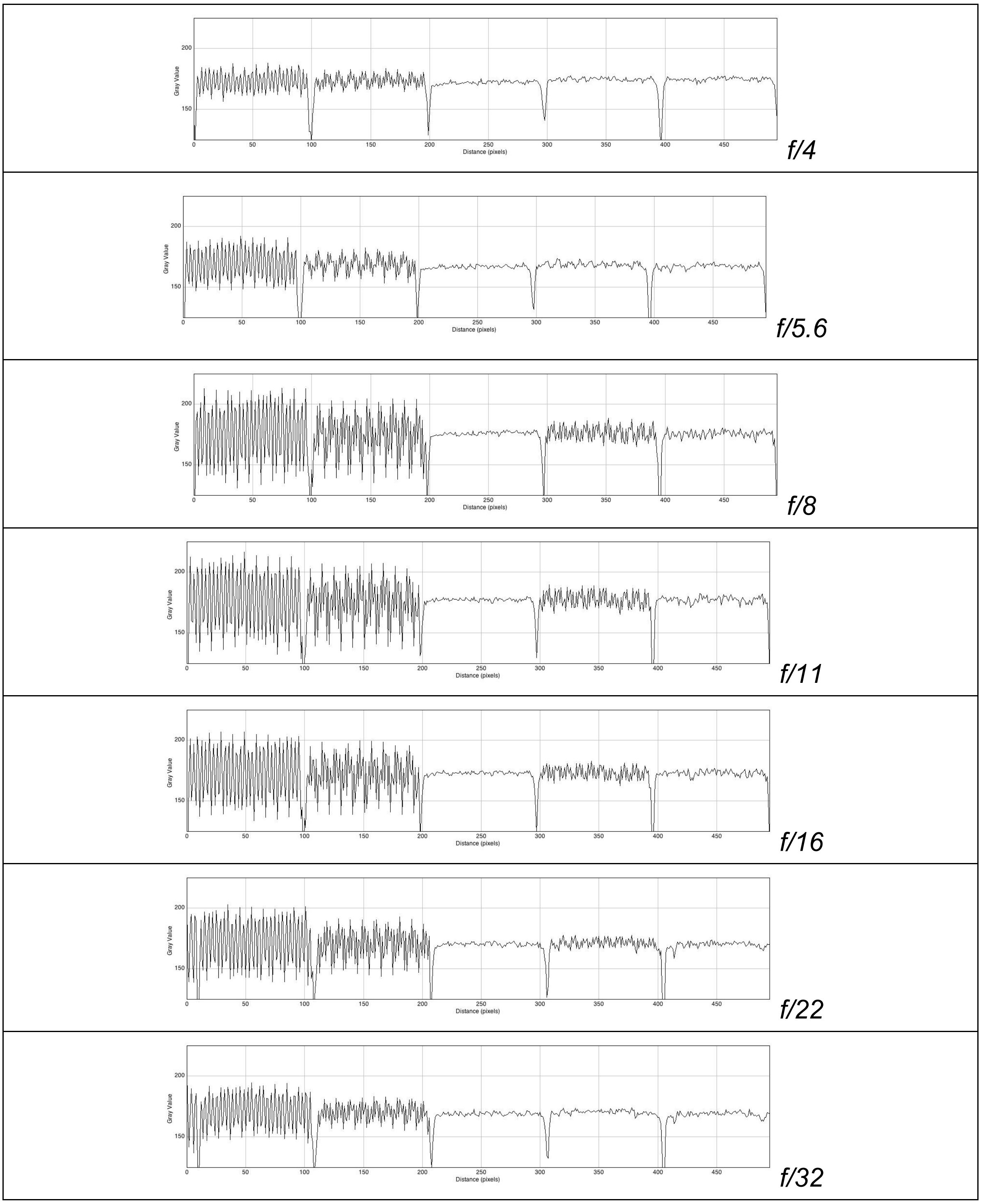


Figure 10 – Set of system responses in terms of aliasing corresponding to the seven lens apertures, with the back in the Sensor+ mode. The pixel grey value plots show the response to five sinusoidal patterns where the central one corresponds with the system limiting frequency.

In the same manner that in the previous case, the plots show the grey value of five image patterns where the central one corresponds with the system limiting frequency. Accordingly, this is the last that can be resolved by the system under test and any response should be expected beyond this limiting frequency. The following conclusions can be derived from the different plots:

- The system is not able to resolve the pattern containing the system limiting frequency.
- At the apertures of *f/4*, *f/5.6* and *f/32* there is not observed any significant response beyond the system Nyquist frequency.
- The plots of the *f/8*, *f/11* and *f/16* apertures show false response or aliasing for the pattern containing frequencies higher than the system Nyquist frequency; this behaviour is maintained but at lower level by the *f/22* aperture plot.
- Working
- Working at the *f/8*, *f/11* and *f/16* apertures there is a risk of system false responses or aliasing if the object to be reproduced contains the respective frequencies. In the case of those frequencies presenting periodic patterns, the image can be affected by *moiré* patterns. At *f/22* the risk is of smaller entity, while present.

6. System OECF Measurement

6.1. Materials and Method

The test target employed to obtain the pixel grey values output from the different optical densities inputs is the Stouffer T4110. The capture was done by transmissive illumination with the same working setup that will be used at the CRDI facilities for the reproduction of translucent items.

The transmissive lighting system consists in a rigid diffuse light box equipped with electronic flash. The system OECF has been measured under six different working conditions combining the two sensor configuration modes, Standard and Sensor+, with the ICC colour profiles created as is detailed in the Section *7. Colour Management*:

- Mode Standard with generic ICC profile and setting the *“film curve”* pre-defined by the Capture One software that monitors the digital back.
- Mode Sensor+ with generic ICC profile and setting the *“film curve”*.
- Mode Standard with generic ICC profile and setting the *“linear curve”*.
- Mode Sensor+ with generic ICC profile and setting the *“linear curve”*.
- Mode Standard with specific ICC profile and setting the *“linear curve”*.
- Mode Sensor+ with specific ICC profile and setting the *“linear curve”*.

6.2. Results of the OECF Measurement

The Figures 11, 12, 13 14, 15 and 16 show the curves OECF obtained indicating the different camera settings employed. All plots are accompanied by a regression line that helps to detect the more or less departure from a linear response.

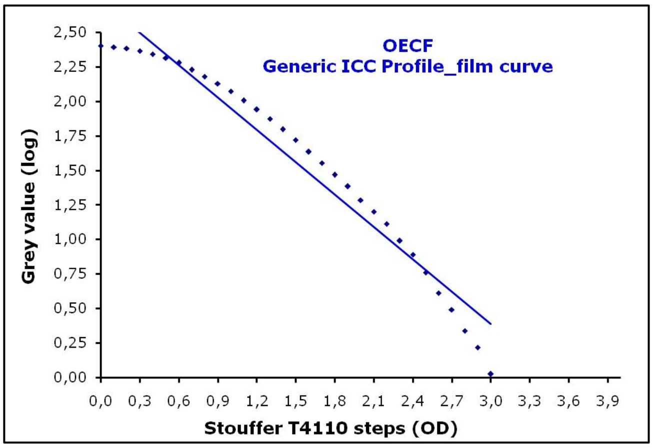


Figure 11 – OECF curve from the sensor in the Standard configuration mode, software curve setting “film curve” and generic colour profile.

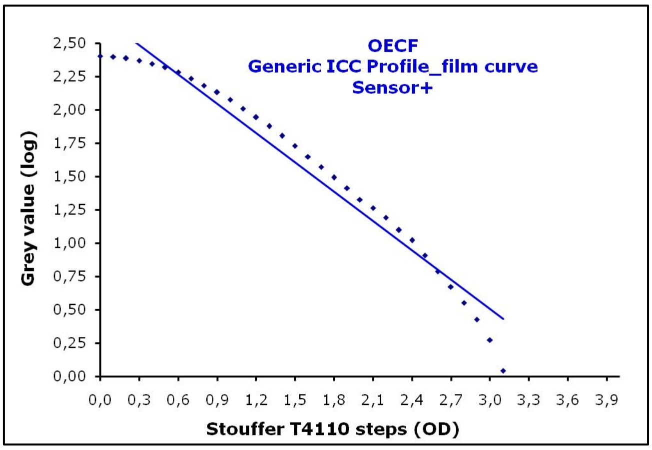


Figure 12 – OECF curve from the sensor in the Sensor+ configuration mode, software curve setting "film curve" and generic colour profile.

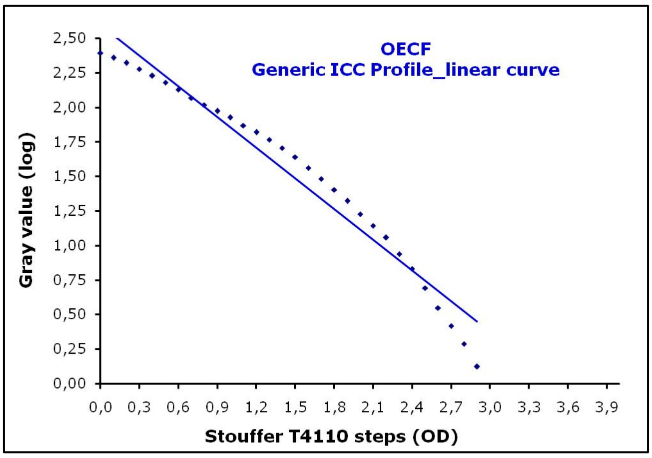


Figure 13 – OECF curve from the sensor in the Standard configuration mode, software curve setting "linear curve" and generic colour profile.

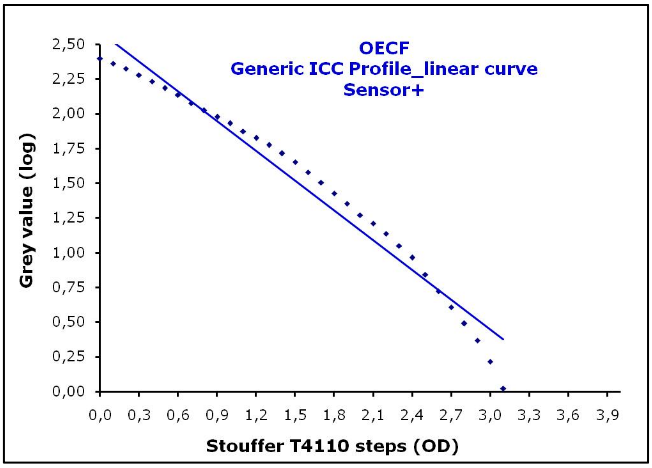


Figure 14 – OECF curve from the sensor in the Sensor+ configuration mode, software curve setting "linear curve" and generic colour profile.

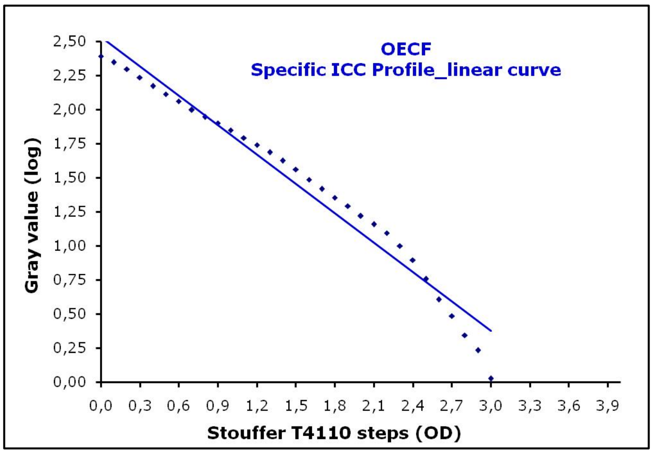


Figure 15 – OECF curve from the sensor in the Standard configuration mode, software curve setting "linear curve" and specific colour profile.

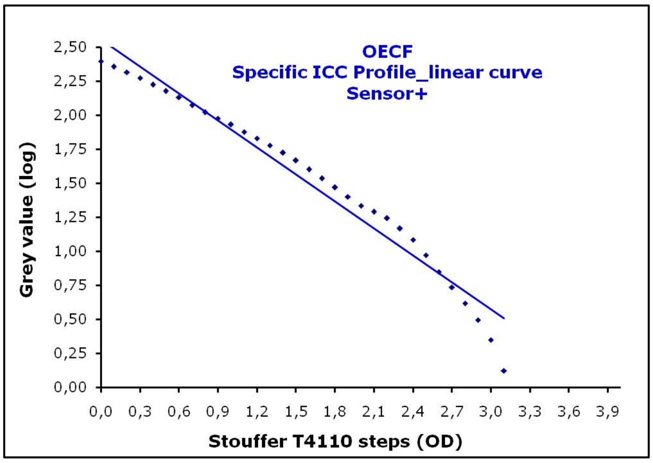


Figure 16 – OECF curve from the sensor in the Sensor+ configuration mode, software curve setting "linear curve" and specific colour profile.

The dynamic range (DR) obtained is similar I all cases, between *10EV* and *10.5EV*. The differences are related with the curve shape; this must be in turn related with the different software curve settings and ICC profiles applied in each case. The wider differences are always located at the curve highlight region, depending on the software curve applied; the *"film curve"* adjustments present a less linear response for the highlights.

Conversely, the setting *"linear curve"* shows a response in general closer to the ideal linear response. This is why is recommended to work using this *"linear curve"* setting because it proportions files that can be improved in any way without the risk to lose highlights information.

In all cases the system is able to record a DR allowing for a density range in the item to be reproduced of 3.0 or 3.15OD, corresponding the higher values to the Sensor+ configuration.

7. Colour Management

7.1. Introduction

Capture One contains some tools to control color reproduction when taking and processing images; these tools allow the assignation of a camera ICC Profile when doing the demosaicing and the conversion to a standard ICC Profile when processing the image. For every camera model, Capture One offers different generic ICC Profiles, depending on the light conditions. These generic ICC Profiles are useful for general photography, but creating specific ICC Profiles is recommendable when the camera is used to make accurate reproductions.

In the case of CRDI, specific ICC Profiles have been created for every capture conditions and the results have been evaluated to analyze the convenience of applying these specific ICC Profiles versus generic Profiles.

7.2. ICC Profiles Creation

In order to achieve a more accurate color reproduction and to analyze the optimum work settings, specific ICC Profiles have been created for the different capture conditions of the CRDI:

- Opaque materials using standard mode.
- Opaque materials with covering glass.
- Opaque materials using Sensor+ mode.
- Opaque materials with covering glass and Sensor+ mode.
- Transparent materials using standard mode.
- Transparent material with covering glass.
- Transparent materials using Sensor+ mode.
- Transparent materials with covering glass and Sensor+ mode.

Applying different ICC Profiles for each condition is necessary because the use of a covering glass and working with Sensor+ mode are factors that can affect color reproduction.

ICC Profiles have been created using the IT8.7/1 Color Chart for transparent materials and the IT8.7/2 Color Chart for opaque materials. Both Color Charts have been photographed with all the described conditions and managed with ProfileMaker software. The resultant ICC Profiles will be applied as camera profiles, using Capture One tools.

Prior to analyze the results of applying generic and specific camera profiles, the convenience of converting images from camera profile to AdobeRGB color space has been evaluated. It is important to take in account that converting all images to AdobeRGB has some advantages:

- All archive images have the same color space
- Specific ICC Profiles are wider than the color spaces of visualization devices (monitors and printing systems). This can lead to problems in color visualization, while AdobeRGB is a standard color space that allows a correct optimization to the different exit options.

- When sending images to external image managers (i.e. Printing services), the use of AdobeRGB ensures the correct color management because is used in all standardized color management systems.

An image of the color chart with the camera ICC Profile and an image converted to AdobeRGB have been compared, measuring color difference (ΔE) of the color patches. The results are not enough different to consider that converting images to AdobeRGB is not a good option (see Table 2), because the advantages of using AdobeRGB are more important than this little deviation and because sooner or later the image will have to be converted to a smaller color space to be displayed or printed. That is why color management and color analysis have been based on assigning the camera ICC Profile and then converting to AdobeRGB when processing the images with Capture One.

Image with camera ICC Profile	Image with camera ICC Profile and converted to AdobeRGB
ΔE = 6,5	ΔE = 7,3

Table 2.

7.3. Colour Reproduction Analysis

Different images of the IT8.7 Color Chart have been obtained by applying the created ICC Profiles (specific ICC Profiles) and the generic Capture One ICC Profile (Phase One P40_Flash V2 b1), with the “linear response” curve supplied by Capture One. All images have been converted to AdobeRGB and saved with tiff format and 16bit.

Lab values of some representative color patches of the color chart have been measured (see Figure 17) and color differences (ΔE) between images and the color chart reference values have been calculated. An average ΔE has been obtained for every image (see Tables 3 and 4).

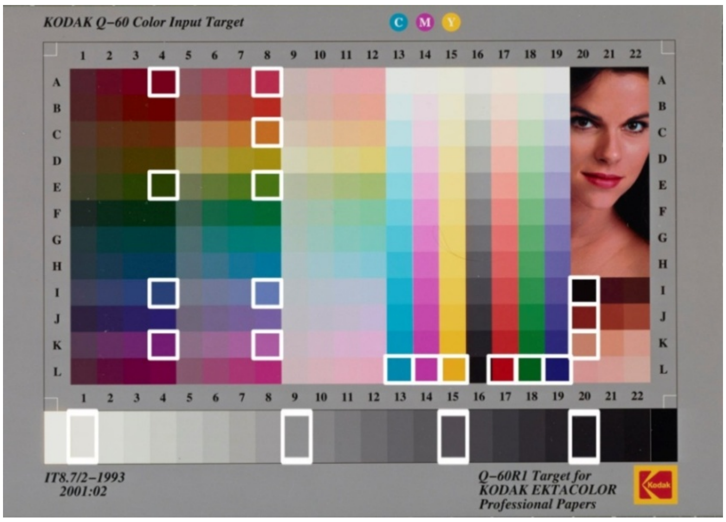


Figure 17. Image of the IT8.7/2 Colour Chart. The white squares indicate the measured patches. The resultant ΔE is the average of these measures.

	Opaque Standard Mode		Opaque Standard Mode with glass		Opaque Sensor+ Mode		Opaque Sensor+ Mode with glass	
	ΔE	Stand. Dev.	**ΔE**	Stand. Dev.	**ΔE**	Stand. Dev.	**ΔE**	Stand. Dev.
Generic ICC Profile (*Phase One P40_Flash V2 b1)*	**7.8**	4.8	**7.5**	5.4	**6.7**	4.6	**7.1**	4.5
Specific ICC Profile	**3.9**	1.9	**3.9**	2.2	**3.5**	2.2	**3.9**	2.6

Table 3. Colour differences of the IT8.7/2 Colour Chart patches for opaque materials, obtained with the generic ICC Profile and the specific ICC Profiles (created for the different capture conditions). Lower ΔE values indicate less colour difference.

	Transparent Standard Mode		Transparent Standard Mode with glass		Transparent Sensor+ Mode		Transparent Sensor+ Mode with glass	
	ΔE	Stand. Dev.	**ΔE**	Stand. Dev.	**ΔE**	Stand. Dev.	**ΔE**	Stand. Dev.
Generic ICC Profile (*Phase One P40_Flash V2 b1)*	**11.1**	8.4	**8.3**	5.9	**7.6**	5.0	**7.6**	5.0
Specific ICC Profile	**4.8**	3.0	**4.6**	2.6	**6.0**	2.0	**5.5**	2.6

Table 4. Colour differences of the IT8.7/1 Colour Chart patches for transparent materials, obtained with the generic ICC Profile and the specific ICC Profiles (created for the different capture conditions). Lower ΔE values indicate less colour difference.

The results show how colour reproduction is more accurate applying the specific camera ICC Profiles and the obtained ΔE values are in the range of acceptability for colour reproduction. Furthermore, standard deviations calculated from ΔE values variation are also lower when applying specific ICC Profiles; this indicates that all colours are reproduced with a more uniform accuracy than when applying the generic ICC Profile. That is why the use of specific ICC Profiles instead of the generic ICC Profile is recommended.

Figure 18 shows colour spaces of the generic ICC Profile (*Phase One P40_Flash V2 b1)* and the specific ICC Profile for Opaque materials, represented in *Lab* colour space. The second one is noticeably wider than the first one. In the case of transparent materials, the specific ICC Profile is not much wider than the generic colour space, but the shape is clearly different, as it can be seen in Figure 19.

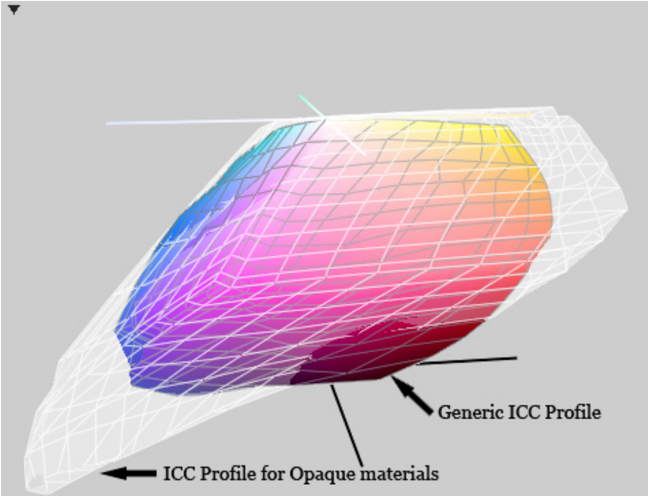


Figure 18. Comparison between generic and opaque ICC Profile. The second one is wider than the generic profile.

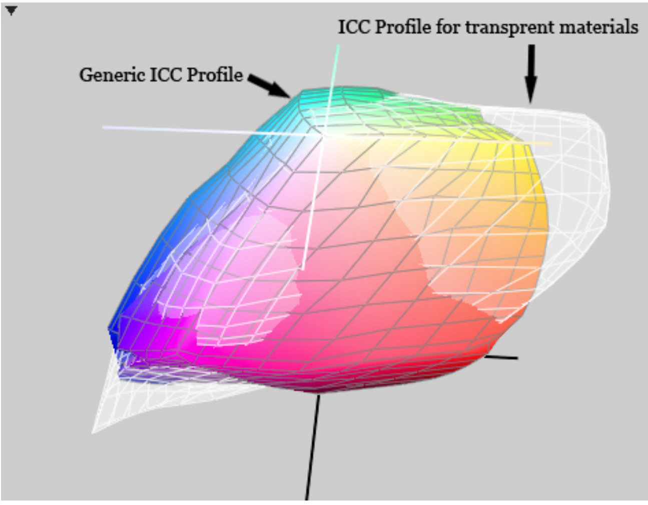


Figure 19. Comparison between generic and transparent ICC Profile. The second one is slightly wider than the generic profile and different in shape.

On the other hand, applying the specific ICC Profile for every different capture settings is important because the use of a covering glass and the activation or deactivation of Sensor+ mode lead to different colour spaces. This can be seen in the colour space graphics shown below (see Figures 20 and 21).

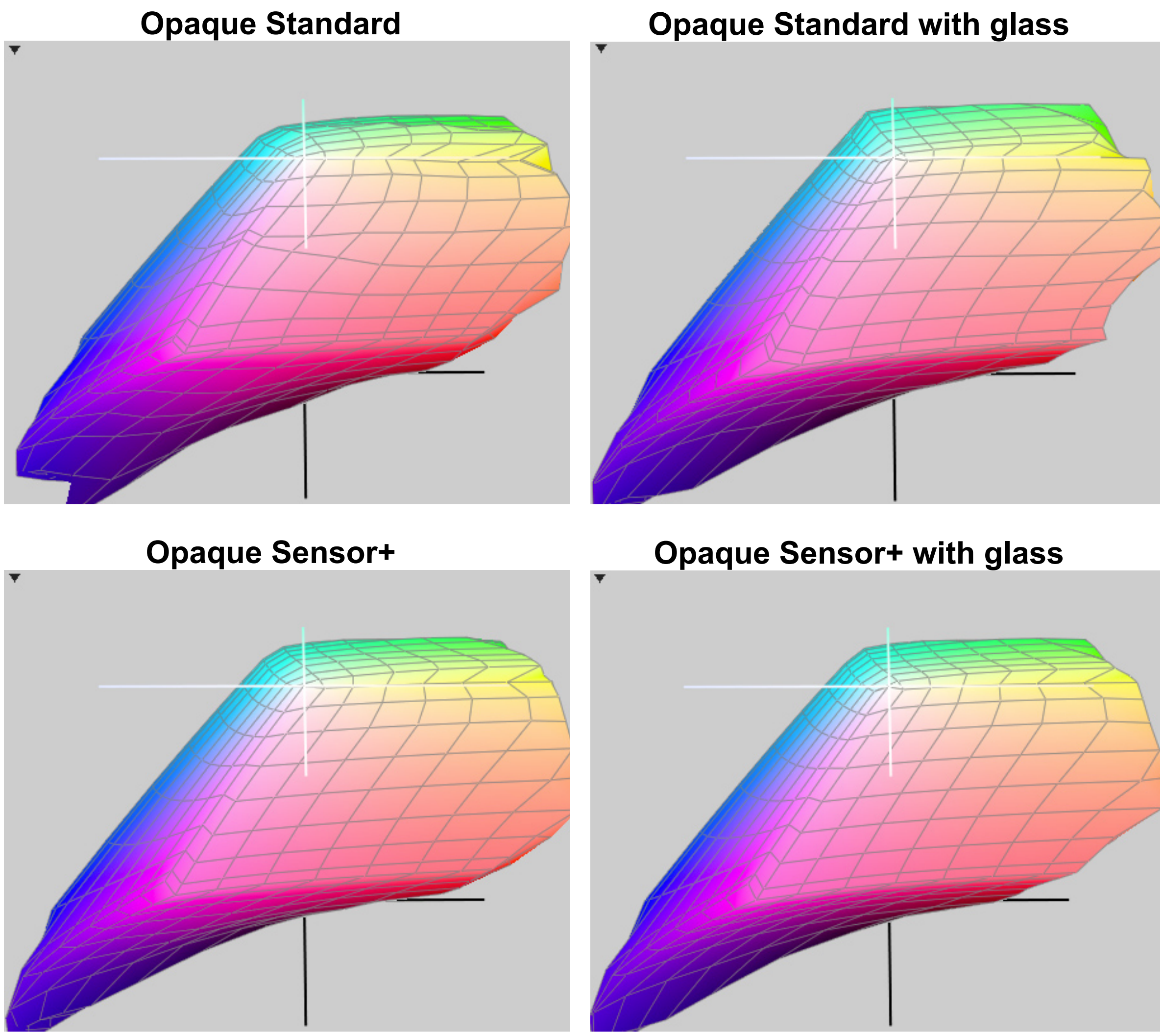


Figure 20. Colour space representation of the specific ICC Profiles for opaque materials. They have similar sizes but different shapes.

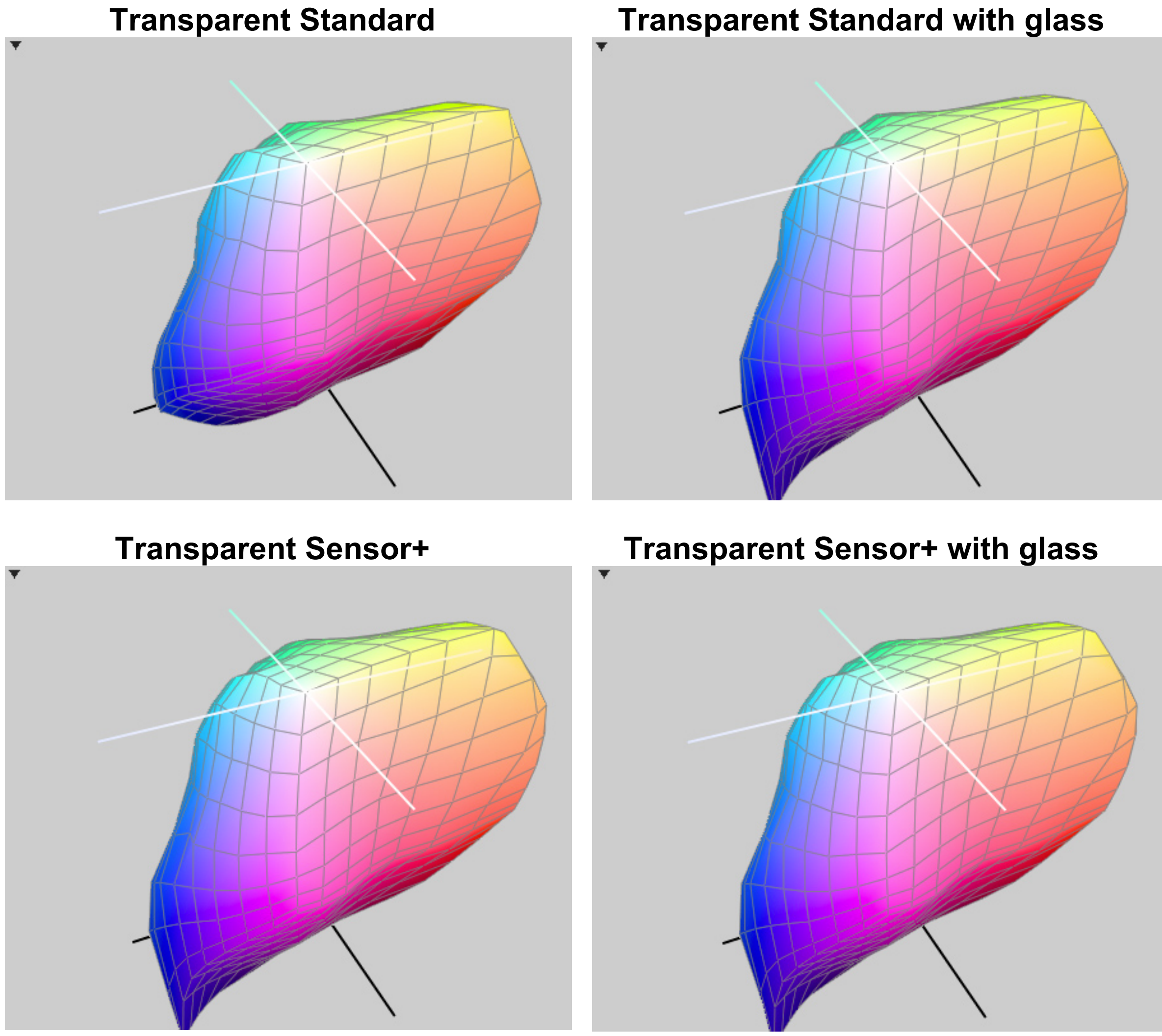


Figure 21. Colour space representation of the specific ICC Profiles for transparent materials. They have similar sizes but different shapes, specially the first one. It is also noticeable than these color spaces are not so wider than those for opaque materials.

8. Conclusions and Recommendations

8.1. Device Performance

- The lens *PhaseOne 120mm AF Macro f/4* do not present residual aberrations of Distortion or TCA. It is not necessary hence to activate the tools provided by the Capture One control software.
- The system MTF results combined with those of the aliasing response permit to structure the following scheme of use capabilities:

- **Originals without a risk to provoke aliasing:**
  - Mode Standard:
    - There is not recommended the use of the ***f/4*** nor the ***f/32*** aperture settings.
    - The apertures ***f/8***, ***f/11*** and ***f/16*** can be used without any restriction.
    - The apertures ***f/5.6*** and ***f/22*** can be used with low performance expectancy.
  - Mode Sensor+:
    - There is not recommended the use of the ***f/4*** nor the ***f/32*** aperture settings.
    - The apertures ***f/5.6***, ***f/8***, ***f/11*** and ***f/16*** can be used without any restriction.
    - The aperture of ***f/22*** can be used with low performance expectancy.
- **Originals or working magnification values with risk to provoke aliasing:**
  - Mode Standard:
    - There is not recommended the use of the ***f/4*** nor the ***f/32*** aperture settings.
    - Aliasing occurs at the ***f/5.6***, ***f/8*** i ***f/11*** aperture range.
    - The aperture ***f/16*** can be used without any restriction.
    - The aperture ***f/22*** can be used with low performance expectancy.
  - Mode Sensor+:
    - There is not recommended the use of the ***f/4*** nor the ***f/32*** aperture settings.
    - Aliasing occurs at the ***f/8***, ***f/11*** i ***f/16*** aperture range.
    - The apertures ***f/5.6***, and ***f/22*** can be used without any restriction.

- In any case and in addition to the previous specifications, if the item or the working magnification constitutes a risk in terms of aliasing, the most recommended is to work at the Standard configuration independently from if the big size file is necessary or not. The file reduction to the desired size can be performed as a post-production sub-sampling.

8.2. Edges Enhancement

From the system ESF measurements as a part of the system MTF measurement method, can be concluded that the best option to enhance the edges of the image contents is as specified in the Table 5. Those setting have been incorporated to the different work styles created in the Capture One software.

CONFIGURATION	STANDARD		SENSOR+	
	Amount	Radio	Amount	Radio
	75%	*2.0*	*50%*	*1.5*

Table 5

8.3. About the Working Procedures

A sort of check in list of operations, verifications and settings to do prior each work session, can be resumed as:

- Verify the distance, height and adjustment of energy output equivalence between the two strobes in the case of opaque originals digitization.
- Adjust the original position over the stand table and the camera height.
- Adjust the focus on the object.
- Choose between the Work Styles depending on the kind of original to be reproduced. This allows to automatically adjust:
    - Standard or Sensor+ configuration mode.
    - Edges enhancement applied.
    - Linear luminance transfer mapping.
    - Colour ICC profile applied.
- Perform an exposure test and adjust as needed by means of measures over a highlight region (white slightly below 255 grey value).
- Prevent, in the case of translucent originals, that the density range over the item do not exceeds *3.00OD*. Otherwise, the capture must be performed in two sequential files adjusting the exposure for lights and shadows respectively.
- Check for the constancy of exposure over the work session.
- Check and adjust periodically the colour calibration of the computer display.

- ALLEN, E. and TRIANTAPHILLIDOU, S. (2011) *The Manual of Photography*. Focal Press, Oxford.
- BOREMAN, Glenn D. (2001) *Modulation Transfer Function in Optical and Electro-Optical Systems*. SPIE Press. Bellingham, Washington, USA.
- FIETE, Robert D. (2010) *Modelling the Imaging Chain of Digital Cameras*. SPIE Press, Bellingham, WA.
- GONZÁLEZ, R. C. y WOODS, R. E. (2002) *Digital Image Processing*, Prentice Hall, Upper Saddle River, NJ, USA.
- HOLST, Gerald C. (2007) *CMOS/CCD Sensors and Camera Systems*. SPIE Press, Bellingham, WA.
- MARTÍNEZ, Bea i MITJÀ, Carles (2008). *Reproducció del color en digitalització d'originals*, 10enes Jornades Antoni Varés Imatge i Recerca. CRDI, Girona.
- MITJÀ, C., ESCOFET, J., TACHÓ, A. & REVUELTA, R. *SE_MTF_2xNyquist plug in for ImageJ*. On line, URL: http://rsb.info.nih.gov/ij/plugins/se-mtf/index.html Last visit: 04/September/2012.
- MITJÀ, C., ESCOFET, J., VEGA, F., *Relationships Between Lens Performance and Different Sensor Sizes in Professional Photographic Still SLR Cameras* in *Current Developments in Lens Design and Optical Engineering X*, edited by Pantazis Z. Mouroulis, R. Barry Johnson, Virendra N. Mahajan, Proceedings of SPIE Vol. 7428 (SPIE, Bellingham, WA 2009) 74280P.
- MITJÀ, Carles i MARTÍNEZ, Bea (2006). *Metodologia de reproducció d'originals Autochrom*. 9nes Jornades Antoni Varés Imatge i Recerca. CRDI, Girona.
- MITJÀ, Carles y ESCOFET, Jaume. *Efecto del aliasing en la MTF de cámaras fotográficas digitales*, 9ª Reunión Nacional de Óptica, Universidad de Vigo2009. Orense.
- MITJÀ, Carles, ESCOFET, Jaume y MARTÍNEZ, Bea. *Criterios de mejora de la nitidez de borde en imágenes fotográficas digitales*, 8ª Reunión Nacional de Óptica, Universidad de Alicante 2006. Alicante.
- PARK, S. K., SCHOWENGERDT, R. & KACZYNSKI, M. (1984) *Modulation Transfer Function Analysis for Sampled Image Systems*. Applied Optics 23, (2572).
- RAY, Sidney F. (1998) *Applied Photographic Optics*. Focal Press. Oxford, UK.
- RUSS, John C. (2002) *The Image Processing Handbook*. CRC Press, Boca Raton, FA.
- WILLIAMS, Don y BURNS, Peter D. (2001) *Diagnostics for Digital Capture Using MTF*. Eastman Kodak Company. Rochester. PICS2001, Montreal (227-232).
- ZAPRYANOV, Georgi y NIKALOVA, Iva (2008) *Comparative Study of Demosaicing Algorithms for Bayer and Pseudo-Random Bayer Color Filter Arrays*. International Scientific Conference *Computer Science '2008.*

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