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Photography — Digital cameras — Chromatic displacement measurements

Photographie — Caméras numériques — Mesurages du déplacement chromatique

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Contents

Foreword

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The committee responsible for this document is ISO/TC 42, *Photography*.

Introduction

Digital still camera images sometimes experience a type of artefact known as chromatic displacement. These artefacts generally appear as colour fringe at boundaries that separate dark and light features. This International Standard defines this type of artefact as chromatic displacement regardless of the source. In the case of multi-sensor digital still cameras, chromatic displacement may be caused by optical, mechanical and electrical factors. In the case of single sensor digital still cameras, there are almost no mechanical and electrical factors, so the chromatic displacement is mainly generated by optical factors and artefacts caused by a mosaic colour filter array. Optical aberrations include lateral chromatic aberration, longitudinal chromatic aberration and comatic aberration.

Lateral chromatic aberration arises when the size of an image changes with the wavelengths of light. Because of this, lateral chromatic aberration is more conspicuous at the peripheral part of the image. Lateral chromatic aberration is rotationally symmetric in an ideal case; however this might not be the case due to manufacturing tolerances.

Longitudinal chromatic aberration arises when the back focus changes with the wavelength of light. Unlike lateral chromatic aberration, longitudinal chromatic aberration may be conspicuous not only in the peripheral part of the image but also in the central portion of the image.

Chromatic displacement by comatic aberration arises when the characteristic of a comatic aberration changes with the wavelengths of light. This phenomenon, known as purple fringe or a colour fringe, is conspicuous at the peripheral part of the image like lateral chromatic aberration. In many cases, comatic aberration can be reduced by using a larger lens f-number (smaller aperture).

Chromatic displacement is emphasized or reduced by image processing.

To measure chromatic displacement, IEC 61146-2 is established by IEC and CIPA DCG-002-2012 based on IEC 61146-2 is also established by CIPA. Furthermore, P1858 - *Standard for Camera Phone Image Quality(CPIQ)* is being developed by IEEE.

This International Standard defines two methods for measuring, the Chromatic displacement and Radial chromatic displacement. Chromatic displacement measures total chromatic displacement encompassing all factors as provided by IEC 61146-2 and CIPA DCG-002-2012. Radial chromatic displacement which measures optical aberration is based on a method developed by the CPIQ and is a main factor in the chromatic aberration of a single sensor digital still camera.

Photography — Digital cameras — Chromatic displacement measurements

1 Scope

This International Standard specifies the definition of chromatic displacement for digital still cameras, test patterns, measurement conditions and methods, so as to enable the comparison of the results of measurement.

The methods of measurement are designed to enable the assessment of the performance of digital still cameras by using image data output by the digital still cameras.

This International Standard does not specify the allowable amount of chromatic displacement.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
chromatic displacement
shift in location of features of different colours in the output image caused by optical, mechanical, electrical and image processing factors

Note 1 to entry: Optical factor include lateral chromatic aberration, longitudinal chromatic aberration, characteristic comatic aberration and others.

Note 2 to entry: It is the displacement of the red (R) and the blue (B) channel in relation to the green (G) channel in an output image.

Note 3 to entry: Chromatic displacement is evaluated by measuring the chromatic displacement in the lateral direction in the image.

2.2
radial chromatic displacement
radial shift in location of different colours in the output image caused by the optical factor called lateral chromatic aberration that may then be influenced by mechanical, electrical and image processing factors

3 Test conditions and methods

3.1 General

The measurement shall be carried out using the digital signals of the output images from the digital still camera with which the test chart is captured.

The following measurement conditions should be used as nominal conditions when measuring the chromatic displacement of a digital still camera. If it is not possible or appropriate to achieve these nominal operating conditions, the actual operating conditions shall be listed along with the reported results.

3.2 Apparatus and hardware

Each test chart shall be specified, together with the lighting conditions such as illuminance, luminance and colour temperature of illumination.

3.2.1 Lighting

Colour temperature of illumination shall be 5 700 K ± 1 000 K. This International Standard does not require a specific illumination level. A level between 1 000 lx to 2 000 lx (in the case of transmissive chart, between 318 cd/m^2 to 637 cd/m^2) is recommended. Special measurement purposes may require other levels. Non-uniformity in illuminance (or luminance) on the chart shall be less than 10 %. The light source(s) should be positioned to provide uniform illumination and produce no glare or specular reflections from the target.

3.2.2 Test chart

3.2.2.1 General

Examples of the test charts are shown in Figure 1 and Figure 2. They can be either reflective test charts or transmissive test chart. The black pattern such as dots or Vs shall represent less than 20 % of the total surface of the image. The chart contrast level should at least be 40:1 and not be higher than 10 000:1.

3.2.2.2 Dot chart

The dot chart contains black circular dots placed on a perfectly regular square grid on a uniform white background. Chromatic displacement and radial chromatic displacement are calculated by measuring the centre positions of the circular dots. The size and the number of dots should be adjusted depending on the number of pixels of the camera and the shooting distance. In the image of the chart, the number of dots on a 4:3 image should be no less than 20 × 15 dots and the diameter of each dot shall be no less than 10 pixels. For a detailed description on how to determine the dots and dot centres in the chart, see 4.2.1.

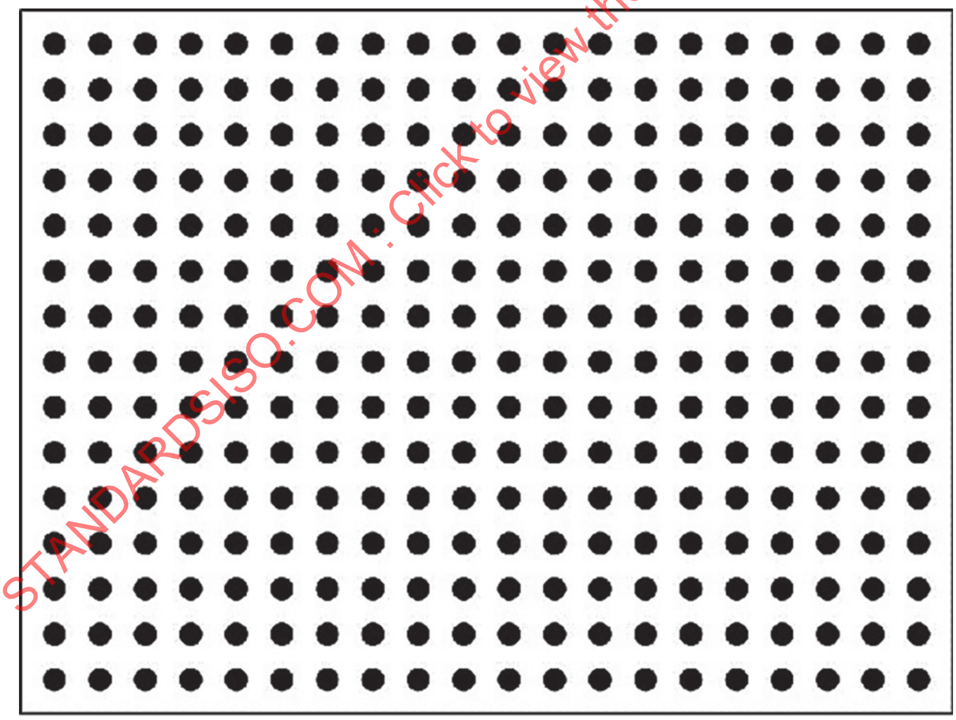


Figure 1 — Dot chart

NOTE ISO 17850, Geometric distortion measurement also adopts the dot chart. Use of the dot chart may reduce the workload required for camera characterization.

3.2.2.3 V pattern chart

The V pattern chart enables the displacement to be measured in both the horizontal and vertical directions by only measuring the displacement at reproduced positions in only the horizontal direction. The method for extracting the geometric values is described in 4.2.2.

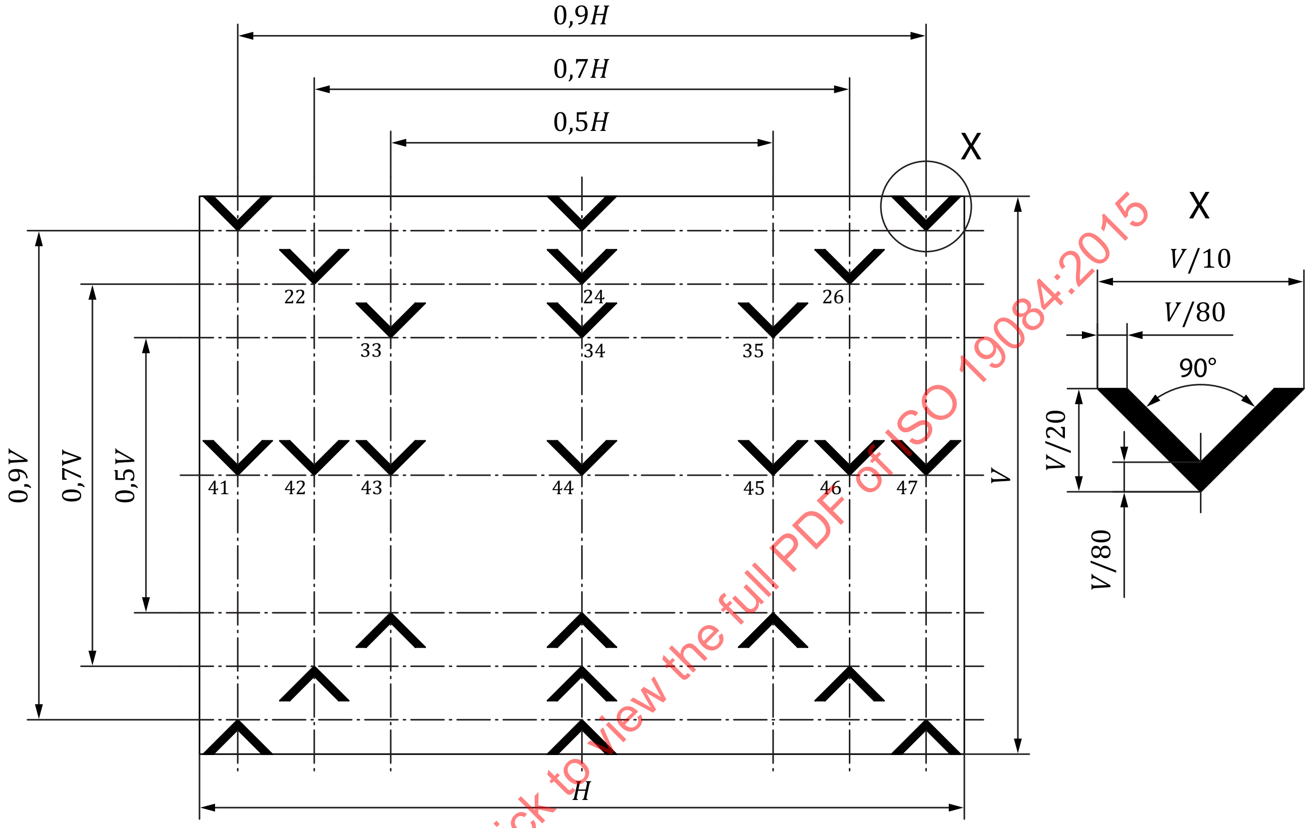


Figure 2 — V pattern chart

3.2.2.4 Requirement for the chart planarity

Non-planarity can be caused by bending of a chart.

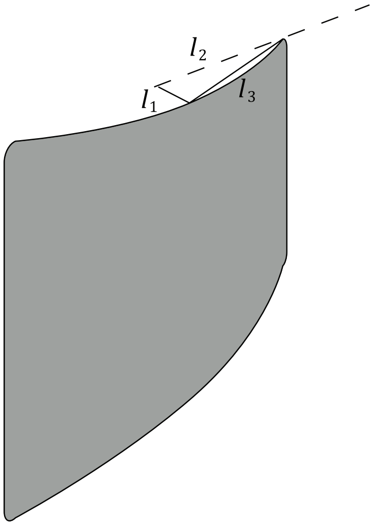
Requirement for the chart planarity is:

Surface deviation which is a height or depth from the reference plane (indicated as bending "l_1" in Figure 3) shall be less than 1,5 % of the width of the chart.

NOTE The required accuracy for a specific measurement sets the requirement for the chart planarity as follows.

For small bending, "l_3" is equal to half the width of the chart to which all numbers are normalized. If bending "l_1" occurs in a chart the effective chart width seen by the camera is "l_2". The difference between l_3 and l_2 causes the deviation in % measured due to the bending of the chart and is calculated by $(1 - l_2/l_3) \times 100$.

The International Standard requirement for local geometric distortion measurement should be a maximum error of 0,045 % due to deviation in planarity of the chart. This equals a maximum deviation in planarity of 3 %. And 3 % of half the width equals to 1,5 % of the full width of the chart.



Deviation in [%]	l_1 / l_3	$l_2 / l_3 = \cos(\sin^{-1} l_1 / l_3)$	Deviation of measured distortion in %
0,5	0,005	0,999 987	0,001 3
1	0,01	0,999 950	0,005 0
2	0,02	0,999 800	0,020 0
3	0,03	0,999 550	0,045 0
4	0,04	0,999 200	0,080 0
5	0,05	0,998 749	0,125 1
6	0,06	0,998 198	0,180 2
8	0,08	0,996 795	0,320 5
9	0,09	0,995 942	0,405 8
10	0,1	0,994 987	0,501 3

Figure 3 — Explanation for the chart planarity and its effect on measured value

3.3 Arrangement of measuring equipment

3.3.1 Reflective test chart

The arrangement of the measuring equipment for a reflective test chart shall be set up as shown in Figure 4. The camera shall be positioned such that it casts no shadow on the chart. The background of the test chart shall be matte black wall or black surround.

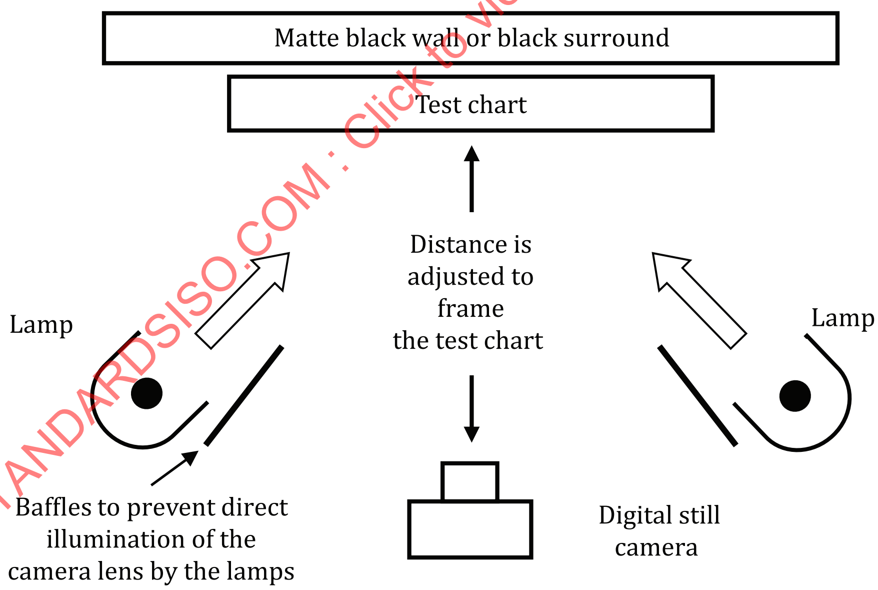


Figure 4 — Arrangement of measuring equipment for reflective test chart

3.3.2 Transmissive test chart

The arrangement of the measuring equipment for a transmissive test chart shall be set up as shown in Figure 5. Instead of a light box, an integrating sphere may be used. Regardless of which light source is used, the illumination shall be diffuse and uniform on the chart plane consistent with the requirement in 3.2.1.

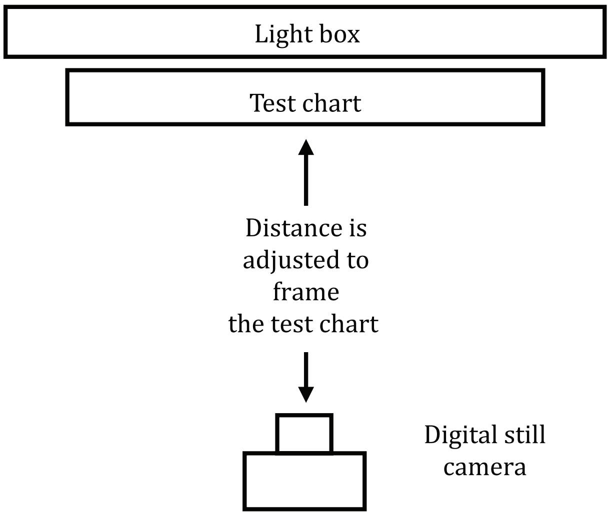


Figure 5 — Arrangement of measuring equipment for transmissive test chart

3.3.3 Positioning of the camera

The chart needs to be orthogonal to the optical axis. The alignment can be performed using a mirror set up on the target plane (i.e. parallel to the target plane) as shown in Figure 6.

Pan, tilt and laterally displace the camera position to the left, right, up and down until the centre point of the taking lens in the image of the camera in the viewfinder is at the image centre.

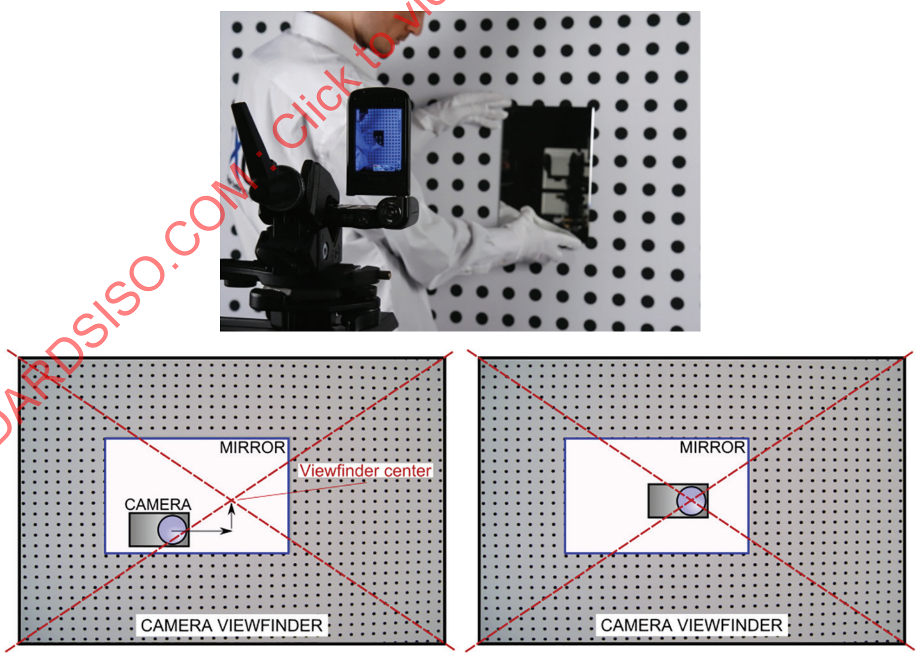


Figure 6 — Alignment of the camera with the target plane using a mirror

If the mirror is not available or the positioning method is not applicable, a manual alignment using the lines of dots in the chart shall be performed so that the intersection of the central horizontal and vertical lines of the dots is in the centre of the image. For each horizontal line, the lines shall be oriented parallel to the horizontal image borders meaning that the line shall be at the same image height for the same distances from the vertical centre of the image.

3.4 Image/camera settings

The camera should be set for auto-exposure and the mean digital value in the image shall be reported. If exposure adjustment is available, exposure should be adjusted to give a mean value of the whole chart between 110 and 160. The mean value is calculated on the output image including black pattern and white background. The image should not be clipped in either bright or dark parts of the chart. White balance should be adjusted to render the centre of the image as neutral as possible. The focusing shall be such that the centre of the image is in focus.

Chromatic displacement is strongly affected by camera settings, such as the f-number, the focal length, and the distance to the object, and these settings should be set preferentially to their factory shipping values. Depending on the purpose of the measurement, the camera settings, such as ISO sensitivity and other image settings, may be adjusted in the following manner:

ISO sensitivity and exposure time may be adjusted so that no visible noise or no banding caused by light source flicker is observed in image. The aperture number and focal length shall be reported along with the ISO sensitivity and the exposure time. More precisely, the ISO sensitivity of the camera may be set to the minimum so as to minimize noise.

The user settings such as colour and contrast may be deactivated. If possible, compression and sharpness should be set to their minimum values. If colour encoding is not sRGB, for example opRGB, it shall be reported.

4 Analytical approach

4.1 General

As the first step for each of the test chart objects the horizontal and vertical distances between the green and the red channel (ΔR_{H_i}, ΔR_{V_i}) and the green and the blue channel (ΔB_{H_i}, ΔB_{V_i}) need to be determined (see Figure 7).

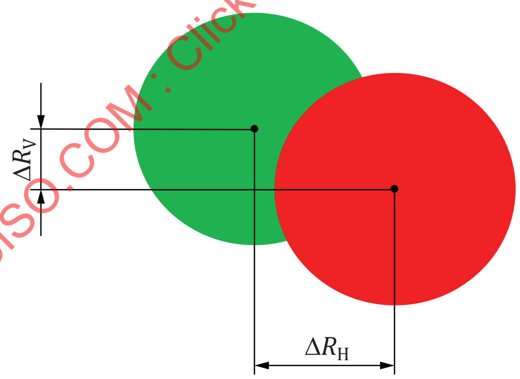


Figure 7 — ΔR_H and ΔR_V

4.2 Determination of displacement

4.2.1 Dot chart

The following are the steps of the measurement:

— extract the dots;

— determine precisely the position of the centre of the dots;

— determine the ΔR_{H_i}, ΔR_{V_i} by comparing the position of the red or blue dots with the position of green dots.

4.2.2 V pattern chart

With reference to Figure 8, measurement shall be carried out by measuring a, a', b, and b', or the number of displaced pixels in the horizontal direction between the B or R channel and G channel at each position of V patterns. The offsets a, a', b, and b' shall be measured from the origins c, d, e, and f, respectively, where the selected line cross over the V patterns in the reference channel, namely, c for a, d for a' e for b and f for b'. Calculation shall be carried out by the following formulas to obtain ΔR_{H_i}, and ΔB_{H_i}, or the amounts of displaced pixels in the horizontal direction and ΔR_{V_i}, and ΔB_{V_i}, or those in the vertical direction between the B or R channel and G channel at each position of V patterns.

Horizontal and vertical displacements ΔH and ΔV shall be calculated by the following formulae:

$$\Delta H = \frac{A + B}{2} \tag{1}$$

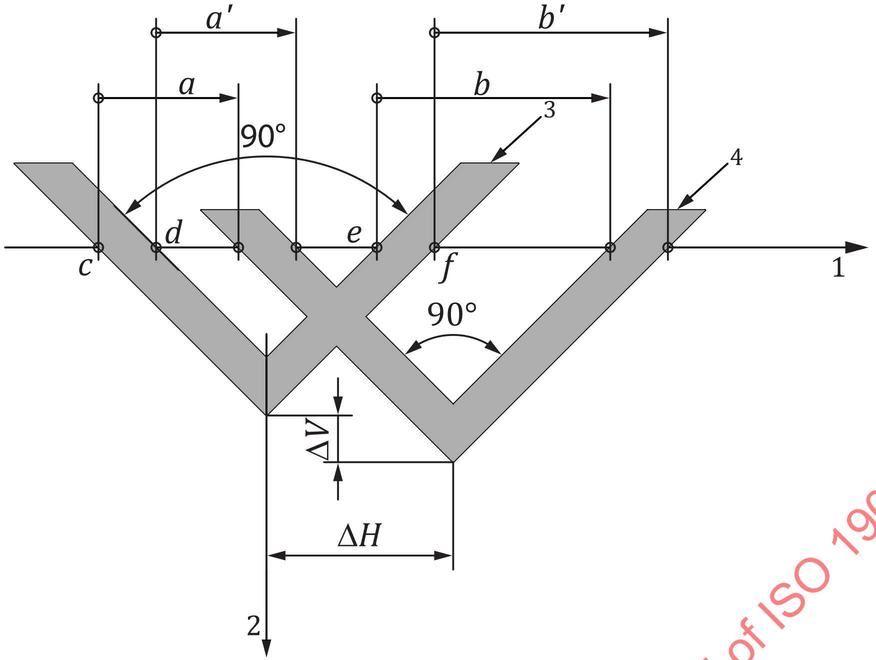
$$\Delta V = \frac{A - B}{2} \tag{2}$$

where

$$A = \frac{a + a'}{2} \tag{3}$$

$$B = \frac{b + b'}{2} \tag{4}$$

ΔR_H and ΔR_V are the ΔH and ΔV of G channel and R channel. ΔB_H and ΔB_V are the ΔH and ΔV of G channel and B channel.



Key

Components

1 H direction

2 V direction

3 G channel

4 R or B channel

Figure 8 — Method of calculating displacement

4.3 Chromatic displacement (CD)

4.3.1 Numerical definition

The chromatic displacement in pixels (ΔR_{CDabs}, ΔB_{CDabs}) shall be calculated as follows:

$$\Delta R_{\text{CDabs\_i}} = \sqrt{\left(\Delta R_{\text{H\_i}}\right)^2 + \left(\Delta R_{\text{V\_i}}\right)^2} \quad (5)$$

$$\Delta B_{\text{CDabs\_i}} = \sqrt{\left(\Delta B_{\text{H\_i}}\right)^2 + \left(\Delta B_{\text{V\_i}}\right)^2} \quad (6)$$

These formulae provide the geometric distance between the structures in pixels.

The relative chromatic displacement (ΔR_{CDrel}, ΔB_{CDrel}) is defined by the ratio of chromatic displacement to the diagonal length of the image. The relative chromatic displacement shall be calculated as follows:

$$\Delta R_{\text{CDrel\_i}} = \sqrt{\frac{\left(\Delta R_{\text{H\_i}}\right)^2 + \left(\Delta R_{\text{V\_i}}\right)^2}{H^2 + V^2}} \times 100\% \quad (7)$$

$$\Delta B_{\text{CDrel\_i}} = \sqrt{\frac{\left(\Delta B_{\text{H\_i}}\right)^2 + \left(\Delta B_{\text{V\_i}}\right)^2}{H^2 + V^2}} \times 100\% \quad (8)$$

where

$\Delta R_{\text{CDrel\_i}}$, $\Delta R_{\text{CDabs\_i}}$	chromatic displacement of Red channel;
$\Delta B_{\text{CDrel\_i}}$, $\Delta B_{\text{CDabs\_i}}$	chromatic displacement of Blue channel;
H, V	number of output pixels in the horizontal and vertical directions

The maximum value of the chromatic displacement in the Red channel [$\Delta R_{\text{CDabs\_i(max)}}$] or in the Blue channel [$\Delta B_{\text{CDabs\_i(max)}}$] shall be $\Delta C_{\text{i\_CDabs}}$.

The larger of the maximum values of the relative chromatic displacement in the Red channel ($\Delta R_{\text{CDrel\_i(max)}}$) or that in the Blue channel ($\Delta B_{\text{CDrel\_i(max)}}$) shall be $\Delta C_{\text{i\_CDrel}}$.

4.4 Radial chromatic displacement (RCD)

4.4.1 Numerical definition

For each of the R and B channels, the radial position difference with respect to the G channel is measured on each dot and plotted as a function of the distance of the green channel to the image centre. When the optical system of the lens is perfectly rotationally symmetric, lateral chromatic aberration is also rotationally symmetric. Sometimes it may not be rotationally symmetric due to manufacturing tolerances, etc. Only the rotationally symmetric components are measured in this International Standard.

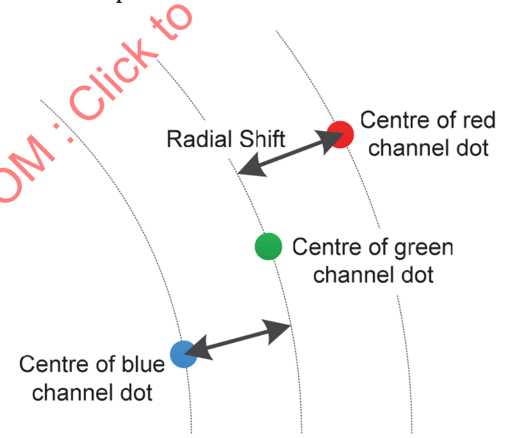


Figure 9 — Illustration of radial chromatic displacement and its radial approximation

The radial chromatic displacement in pixels (ΔR_{RCDabs}, ΔB_{RCDabs}) shall be calculated as follows:

$$\Delta R_{\text{RCDabs\_i}} = \sqrt{\left(G_{\text{H\_i}}\right)^2 + \left(G_{\text{V\_i}}\right)^2} - \sqrt{\left(R_{\text{H\_i}}\right)^2 + \left(R_{\text{V\_i}}\right)^2} \quad (9)$$

$$\Delta B_{\text{RCDabs\_i}} = \sqrt{\left(G_{\text{H\_i}}\right)^2 + \left(G_{\text{V\_i}}\right)^2} - \sqrt{\left(B_{\text{H\_i}}\right)^2 + \left(B_{\text{V\_i}}\right)^2} \qquad (10)$$

The relative radial chromatic displacement (ΔR_{RCDrel}, ΔB_{RCDrel}) is defined by the ratio of radial chromatic displacement to the diagonal length of the image. The relative radial chromatic displacement shall be calculated as follows:

$$\Delta R_{\text{RCDrel\_i}} = \frac{\sqrt{\left(G_{\text{H\_i}}\right)^2 + \left(G_{\text{V\_i}}\right)^2} - \sqrt{\left(R_{\text{H\_i}}\right)^2 + \left(R_{\text{V\_i}}\right)^2}}{\sqrt{H^2 + V^2}} \times 100\% \qquad (11)$$

$$\Delta B_{\text{RCDrel\_i}} = \frac{\sqrt{\left(G_{\text{H\_i}}\right)^2 + \left(G_{\text{V\_i}}\right)^2} - \sqrt{\left(B_{\text{H\_i}}\right)^2 + \left(B_{\text{V\_i}}\right)^2}}{\sqrt{H^2 + V^2}} \times 100\% \qquad (12)$$

where

G_H is the horizontal distance of the dot centre for the green channel from the centre of the image;

G_V is the vertical distance of the dot centre for the green channel from the centre of the image;

H is the number of output pixels in the horizontal direction;

V is the number of output pixels in the vertical direction;

the red and blue channels are named in an equivalent manner.

5 Presentations of results

5.1 Chromatic displacement

Either, or both chromatic displacement in pixels and relative chromatic displacement may be reported. The value with the largest displacement of the chromatic displacement of each position shall be stated. It is recommended also to indicate such position.

The f-number, focal length of lens, chart distance, lighting illuminance, and horizontal and vertical of number of recorded pixels shall be reported.

The chromatic displacement in pixels shall be reported as follows:

Presentation example 1:

Displacement: 1,5 pixels in approximate (x = −500, y = 1 500) pixel relative to image centre

Focal length: 4,6 mm

f-Number: 2,8

Number of Recorded Pixels: 5 472 × 3 648

Lighting illuminance: 1 500 lx

Chart distance: 1,5 m

Presentation example 2:

Displacement: 1,5 pixels (90 % of maximum image height)

Focal length: 4,6 mm (Wide-end)

f-Number: 2,8

Number of Recorded Pixels: 5 472 × 3 648

Lighting illuminance: 1 500 lx

Chart distance: 1,5 m

The relative chromatic displacement shall be reported as follows:

Presentation example 1:

Displacement: 0,10 % in approximate (x = −500, y = 1 500) pixel relative to image centre

Focal length: 4,6 mm

f-Number: 2,8

Number of Recorded Pixels: 5 472 × 3 648

Lighting illuminance: 1 500 lx

Chart distance: 1,5 m

Presentation example 2:

Displacement: 0,10 % (90 % of maximum image height)

Focal length: 4,6 mm (Wide-end)

f-Number: 2,8

Number of Recorded Pixels: 5 472 × 3 648

Lighting illuminance: 1 500 lx

Chart distance: 1,5 m

The relative values shall be given in units of 0,01 % (round the value up to a hundredth of a percent).

5.2 Radial chromatic displacement

The red and blue RCD shall be plotted as a function of radial field position of the green channel. A third-order polynomial fit shall be applied to each channel to smooth the results. The valid range for the fit is from the smallest dot centre field position to the largest dot centre field position.

The radial chromatic displacement objective metric is the worst value of the best-fit curve and the worst value among all measured values. The values are calculated over the whole field and expressed as a percentage of the image height. Worst value of the best fit curve statistically indicates a characteristic of rotationally symmetric component by calculating best-fit curve. Worst value among all measured value indicates some indexes, for example its optical asymmetric, limitation of use and deviations. The worst value of the best-fit curve shall be reported. The worst value among all measured values should be reported. Both values shall be distinguished in presentation. An example is shown as follows.