DOI: 10.25039/TN.014.2023

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

TECHNICAL NOTE

Example Luminance Measurement Setup for UGR

CIE TN 014:2023

CIE Technical Notes (TN) are concise informative technical papers, which either have been prepared by a TC, in which case they will usually form only a part of the outputs from that TC, or through the auspices of a Division Reportership.

This Technical Note has been prepared by CIE Division Reporter 3-36 of Division 3 “Interior Environment and Lighting Design”. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by all with an interest in excellence in light and lighting. The information provided here is advisory, and not mandatory.

Any mention of organizations or products does not imply endorsement by the CIE. Whilst every care has been taken in the compilation of any lists, up to the time of going to press, these may not be comprehensive.

© CIE 2023 - All rights reserved

This Technical Note has been prepared by DR 3-36, “Luminance Measurement for UGR”. The reportership comes under Division 3 “Interior Environment and Lighting Design”. The author of this Technical Note is:

Vissenberg, M.C.J.M (Reporter)	The Netherlands

The following experts are gratefully acknowledged for the measurement setup and measurements described in this Technical Note.

Embrechts, M	The Netherlands
Klej, A.	The Netherlands

CONTENTS

EXAMPLE LUMINANCE MEASUREMENT SETUP FOR UGR

Summary

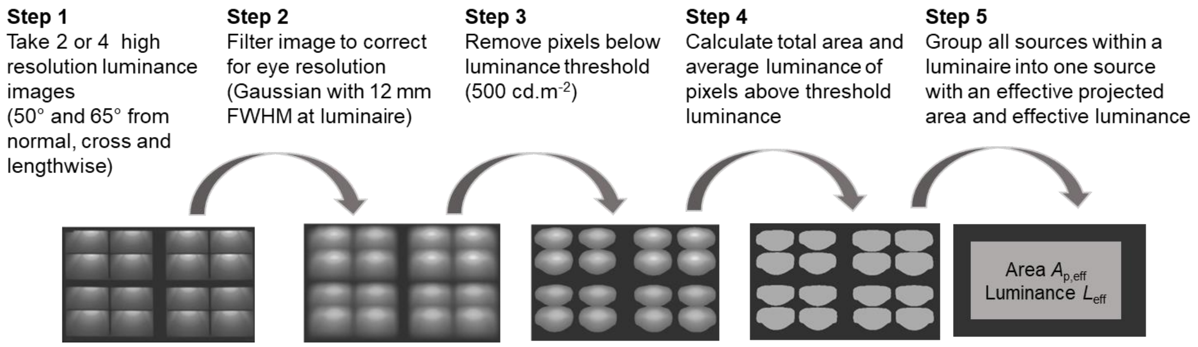
Technical Report CIE 232:2019 specifies a supplement to the Unified Glare Rating (UGR) method to determine the glare source area in case the glare source has a non-uniform luminance. The method requires high dynamic range (HDR) luminance images of the glare source. In this Technical Note, an HDR luminance image measurement setup is described that can be used to generate images according to CIE 232:2019 specifications. Two examples of such measurements are given, including the image analysis and the determination of the glare source dimensions. Although some guidance is given, this Technical Note is not intended to be a detailed measurement guide and should be used in conjunction with other CIE publications.

1 Introduction

Technical Report CIE 232:2019 “Discomfort caused by glare from sources with a non-uniform source luminance” describes a measurement method to determine the glare source area to be used in the calculation of the Unified Glare Rating (UGR) (CIE 2019). The measurement involves high dynamic range (HDR) luminance imaging of the glare source using an imaging luminance measurement device (ILMD), also referred to as a luminance camera, at a few specified measurement angles and with a specified image resolution. While the report clearly describes the luminance image specifications, it does not describe how such images can be measured.

NOTE: Rigorously speaking, an “image” is a representation of the set of measurements which is used for visual analysis; however, in this document the term “image” is also used to describe the set of measurements.

Figure 1 summarizes the image measurement and analysis method according to CIE 232: 2019.



NOTE The FWHM is the full width at half maximum of a distribution function.

Figure 1 – Overview of the measurement and image processing steps that are required to obtain the effective projected area and effective luminance (Figure 2 of CIE 232:2019)

The result is an effective luminance, L_{eff}, and an effective projected area, $A_{\mathrm{p,eff}}$, of the non-uniform glare source. These quantities can then either be used to compute a correction to UGR or to redefine the projected area such that no correction is needed. In the latter case, this new projected area $A_{\mathrm{p,new}}$ is

$$A_{\mathrm{p,new}} = \frac{I^2}{L_{\mathrm{eff}}^2 \; A_{\mathrm{p,eff}}} \tag{1}$$

where I is the luminous intensity of the glare source in the measurement direction.

Once the new projected glare source area is determined for the specified measurement angles, the glare source dimensions need to be calculated by projecting back onto a basic shape. This shape is typically a rectangle, circle, rectangular block, cylinder, or sphere (see (CIE 1983) or (CIE 1995) for examples). Glare source dimensions, in combination with the luminous intensity table, can then be used to calculate UGR in the conventional manner (as described in (CIE 1995; CIE 2010). This is the main advantage of using the redefined projected area: lighting practitioners can apply the UGR method as before, without needing to consider HDR luminance image measurements. These specialized measurements need only to be done once by the luminaire manufacturer (or outsourced to a photometric laboratory) to determine the correct source dimensions.

In this Technical Note, an HDR luminance image measurement setup is described that can be used to generate images according to CIE 232:2019 specifications. Two examples of such measurements are given, including the image analysis and the determination of the glare source dimensions.

2 Luminance images as specified in CIE 232:2019

The luminance image is specified in (CIE 2019, 3.2):

“To determine either luminance uniformity, effective source area or effective source luminance, a luminance image is required. The resolution of this image needs to be sufficiently high to incorporate all relevant luminance variations. … the measurement angles may be limited to two relevant angles:

- 25° ± 5° to the horizontal plane (65° ± 5° to the vertical plane),
- 40° ± 5° to the horizontal plane (50° ± 5° to the vertical plane).

... If the luminaire or the luminous intensity distribution is not symmetric, this image should be taken from a longitudinal direction as well as from a transverse direction.”

The ± 5° range was introduced to account for unavoidable variations in measurement angle over the source surface. While the source centre should be measured at the angles mentioned above, the measurement angle at the edge of the source may deviate up to ± 5°. In the (C,γ) coordinate system, these angles correspond to 65° ± 5° and 50° ± 5° in γ angle respectively.

Also in (CIE 2019, 3.2), the image resolution is specified by “In all cases, the relevant luminance image resolution is 12 mm at the luminous source …. Either the measurement equipment is set to this resolution, or a finer resolution is used in the measurement and the image is blurred to the required resolution by applying a Gaussian filter.”

3 Luminance image measurement setup

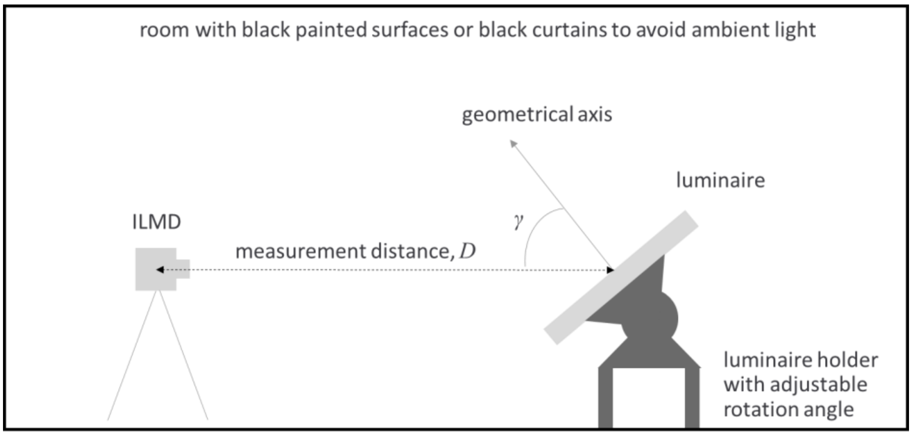
The specification in Clause 2 is defined for the characterization of a single, isolated luminaire. The reason for this is that UGR is determined from photometric data as provided by luminaire manufacturers, which can only be based on measurements on a single luminaire (the application context being undefined). Besides, the method of (CIE 2019) was verified only by experiments that used a single glare source (see Annex A.3 of (CIE 2019)). The fact that only a single, isolated luminaire is characterized simplifies the measurement setup and image analysis considerably, as will be described below. In principle, the method can also apply to wide-angle luminance images that cover the complete field of view of an observer, with multiple glare sources in a single image. This type of measurement is needed to characterize a full lighting installation directly. The differences between single-luminaire measurements and wide-angle measurements for the UGR correction according to (CIE 2019) are also discussed by Funke (2021). It is important to note that a UGR correction method based on wide-angle luminance images of multiple glare sources has not been tested yet.

This Technical Note focuses on a large distance measurement of a single luminaire to obtain the luminance images as specified in Clause 2. The method is characterized by the measurement conditions as described in the following subclauses.

It is important that the measurement instrument is properly characterized and calibrated; however, guidance on this is beyond the scope of this TN. CIE 244:2021 (CIE 2021) provides comprehensive guidance on the characterisation of ILMDs. CIE TC 2-86 (CIE 2023) is currently preparing a Technical Report which will provide additional guidance on the use of ILMDs for glare measurement. The instrument(s) used for the measurement should be calibrated traceable to the SI using appropriate means.

3.1 Image centre aligned with luminaire centre

The example measurement setup is shown in Figure 2. The ILMD is positioned at the same height as and aimed at the centre of the luminaire, which is tilted at the specified angle γ (measurement angle of 65° and 50° with respect to the luminaire geometric axis). For rotationally symmetric luminaires, these two measurements (at γ = 65° and γ = 50°) are sufficient. For quadrant symmetric (also called disymmetric) luminaires, the luminance images are measured along both orthogonal symmetry planes: in total four images. For luminaires with a lower symmetry than rotational or quadrant symmetry, more measurement directions can be needed. This case is not considered here (it is also not considered in the UGR Tabular method of (CIE 1995; CIE 2010)).



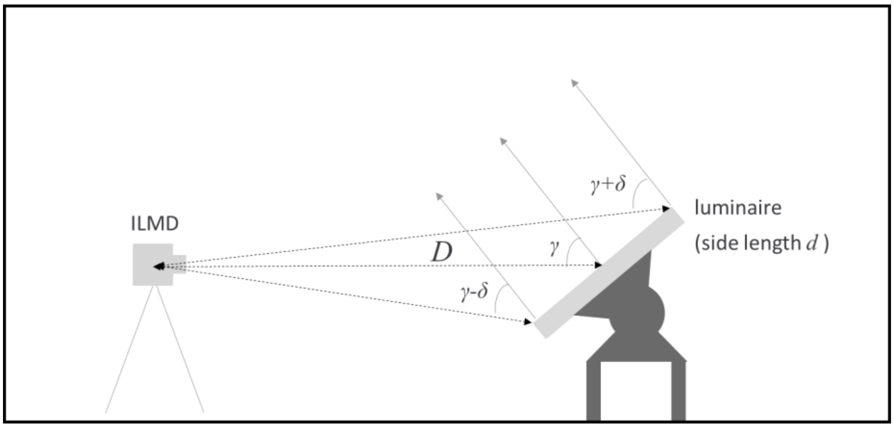
NOTE The measurement distance, D, is the distance between the ILMD body and the centre of the luminaire light exit window, which are usually aligned at the same height. The angle γ is the measurement angle with respect to the geometric axis of the luminaire.

Figure 2 – Measurement setup for image centre aligned with luminaire centre

NOTE: Tilting the luminaire from its designed burning position can change its thermal behaviour and may affect its output. For more information see CIE S 025 (CIE 2015).

3.2 Large measurement distance

The ILMD is positioned at a distance far enough from the luminous source to ensure that the deviation in γ angle from a point anywhere on the source is less than 5° from the γ angle at the source centre. (see Figure 3). This condition can be satisfied when the measurement distance, $D > 4{,}1\ d$, where d is the longest side of the luminaire. This means that $D > 2{,}5$ m distance is needed for a square luminaire with 0,60 m sides, whereas a 1,70 m long luminaire requires a measurement distance, $D > 7{,}0$ m. Note that these are referring to the luminous dimensions of the luminaire, not the physical dimensions. Note also that the size of the source as subtended at the ILMD may be larger than 5° in these conditions.



NOTE The angle δ is the deviation from the γ angle at positions on the luminaire compared with the γ angle at the centre position. The deviation angle δ decreases with increasing measurement distance, D (the value of δ depends on the position on the luminaire as well as the relative position of the luminaire with respect to the ILMD).

Figure 3 – Measurement setup for large measurement distance

The required luminance image resolution is 12 mm. To get a robust result, a luminance image pixel size of at most 1,2 mm/pixel is advised. This high-resolution image is blurred by a Gaussian filter with a full width at half maximum (FWHM) of 12 mm (see Clause 4). This procedure is also used in the data analysis in Annex A.3 of (CIE 2019), as well as by Funke (2021). In general, the pixel size can vary over the image, depending on the type of lens. The advantage of the large distance measurement setup is that the luminance image can be approximated by a square mesh with constant pixel size. Funke (2021) found that for such images, the area summation error is usually negligible, especially for disymmetric luminaires, because the slight deviations from the square grid are also symmetric around the image centre. The constant pixel size approximation simplifies not only the area summation, but also the Gaussian filtering (see Clause 4). This approximation is also used in the data analysis of CIE 232:2019.

3.3 High dynamic range imaging

The luminance image needs to be accurate for luminance values from 500 cd·m^{-2} (the threshold luminance value) up to peak luminance values that may be as high as 10 Mcd·m^{-2} (typical high power LED luminance values). This high dynamic range requirement poses constraints on the ILMD as well as the surrounding. Stray light should be minimized: both from external sources and from light emitted by the source reflecting of other surfaces back onto the source. This may involve painting room surfaces matt black and using black cloths and other baffles to minimize sources of stray light.

The following list is an example ILMD measurement setup which has been used by the author of this TN (the absolute luminance values measured with the ILMD were verified by comparison with measurements made using a spot luminance meter):

a) multiple images with different exposure times are converted to one HDR luminance image; this enables a high dynamic range of up to 1:10 000 000;

b) 25 mm lens (field of view 1,6 m by 2,1 m at 6,0 m measurement distance);

c) three similar Neutral Density (ND) filters (attenuation 60,78, 61,13, and 59,83) are used to adjust the absolute luminance scale (filters can be stacked to increase the attenuation);

d) the ILMD sensor has 2448 by 2048 pixels;

e) a stray light correction algorithm is used to suppress noise in the image;

f) A/D conversion: 14 bit;

g) integration time: 100 µs to 15 s;

h) ILMD manufacturer's specification: variation in pixel luminance value, ΔL < 3 %, variation in pixel colour coordinates, $\Delta(x,y)$ < 0,0020 (for standard illuminant A);

i) uniformity: variation in pixel luminance value over the sensor, ΔL < 2 %;

j) spectral matching: with full size filter matched to $V(\lambda)$ for photopic vision

NOTE 1: Different measurement equipment specifications than the example given above are possible in order to achieve a similar performance.

NOTE 2: If the luminaire output is not DC and the measurement exposure time is not an integer multiple of the power line cycle or modulation frequency of the luminaire then the measurements may be unstable. In such cases, many images may need to be captured and averaged together in order to reduce measurement fluctuations, and care should be taken to ensure that in all images there are not over-exposed pixels.

NOTE 3: Ideally a single ND filter of higher attenuation would be used in preference to stacking multiple ND filters.

3.4 Measurement protocol

The measurement protocol used in this example setup is as follows:

a) Set luminaire sample at correct distance (D > 4,1 x *d*), aimed with its geometric axis in line with the measurement axis between the ILMD and the centre of the sample.

b) Select a lens which is appropriate for the required field of view; in practice, the 25 mm lens works for most luminaire sizes. A 50 mm lens can be used to get a higher resolution for small luminaires.

c) Install no ND filters at the start.

d) Capture a first image (the luminaire sample is OFF).

e) Focus the lens.

f) Align the ILMD or the luminaire sample such that the centre of the luminous area of the sample is in the centre of the luminance image.

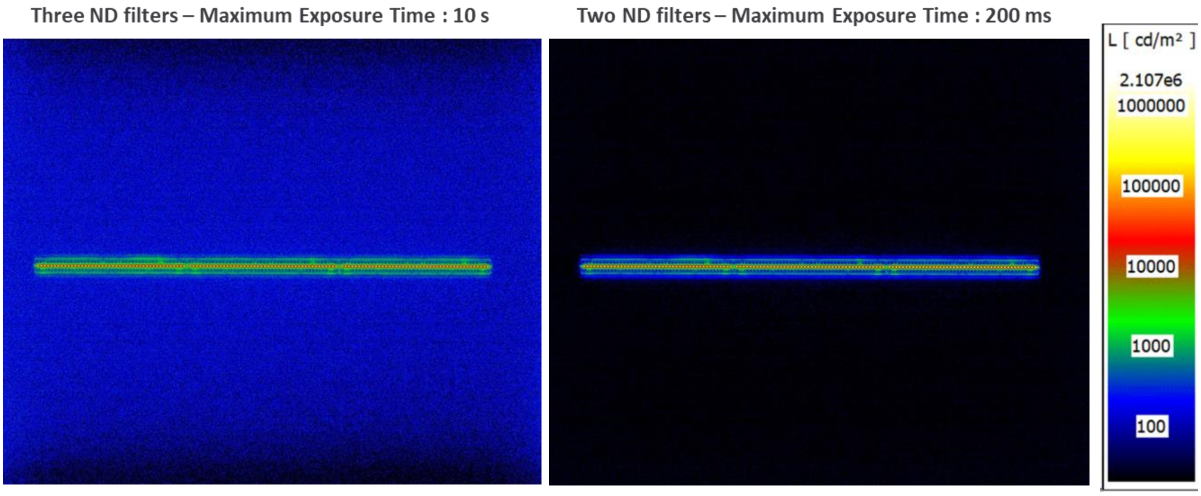
g) Do a geometric calibration by counting the number of pixels along a ruler placed at the centre of the luminaire (assuming constant pixel size) and save the settings.

h) Tilt the luminaire sample to the required measurement angle, switch ON the luminaire sample and allow an adequate time for stabilisation (see for example [reference CIE S 025]).

i) Install ND filters and do a number of measurements to confirm that the exposure time is not too long. Exposure times between 50 ms and 1 s give good results. Best results are obtained with 100 ms to 500 ms to get an acceptable noise level of the luminance pixel values (see Figures 4 and 5).

j) Do a series of luminance measurements at different exposure times to convert into an HDR image.

k) Save image and convert to text file as an array.



Three ND filters – Maximum Exposure Time : 10 s

Two ND filters – Maximum Exposure Time : 200 ms

NOTE Both images use the same logarithmic scale. In case of three stacked ND filters, a very long maximum exposure time of 10 s is needed. The stray light and additional noise present then fail to keep the background level below the required 500 cd·m^{-2} threshold level and the results are unreliable.

Figure 4 – HDR luminance images of a linear LED luminaire, captured with either three (left image) or two (right image) stacked ND filters to avoid over exposure by the LEDs

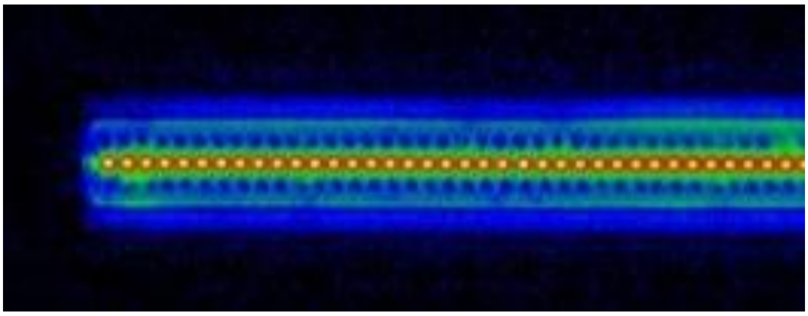


Figure 5 – Close-up view of the right HDR luminance image of Figure 4

4 Luminance image processing

The luminance image is used in (CIE 2019) to determine the luminous area of the glare source. The original image is first filtered to remove details that are not visible. After that, pixels with a luminance below a threshold value of 500 cd·m^{-2} are excluded from the calculations (given a weight of 0). This clause contains an example script for the post processing of luminance images to determine the luminous area of the glare source (the syntax used here is based on the MATLAB programming language, but with some modifications of the syntax, the script is also usable in other programming languages).

NOTE: In this clause, it is assumed all pixels in the luminance image are equal in size, without applying projective rectification. A more rigorous evaluation may be required in other measurement setups, especially for closer measurement distances and/or asymmetric luminaire shapes (see Clause 3.2).

Required inputs for the script are:

- `"Image1":` File containing an array of luminance values (text format, no headers);
- `"resolution":` Pixel resolution of the image in mm/pixel at the luminous source. For the sake of simplicity, this code is applicable to luminance images with square pixels only.

The (peripheral) eye resolution is defined by a Gaussian filter with an FWHM of 12.0 mm. The standard deviation "`sigma`" of this Gaussian filter (in pixels) is

```
sigma = 12.0/(2.35 * resolution)
```

where 2.35 is the numerical value of `2 * sqrt(2*log(2))` (the conversion factor of an FWHM value to a Gaussian standard deviation).

The input luminance image "`Image1`" is filtered according to eye resolution by using the MATLAB command "`imgaussfilt`" to produce the blurred luminance image "`Image2`":

```
Image2 = imgaussfilt(Image1, sigma, 'Filtersize', 2*ceil(3*sigma)+1,
'FilterDomain', 'spatial', 'padding', 'symmetric');
```

The width of the filter is set at seven times "`sigma`" (as defined by `2*ceil(3*sigma)+1`, where the `ceil` function gives the smallest integer greater than the input number). A wider filter slows down the calculation without changing the results significantly. A narrower filter, however, speeds up the calculation, but it leads to errors. If the filter width is not defined, the MATLAB program can use a default value that is too small, which can lead to an underestimate of the glare source area.

The area per pixel (in m^2) is given by

```
pixelarea = ( 0.001 * resolution )^2;
```

The total luminous intensity in the luminance image "`Itot`" follows from the product of this pixel area and the summation of all luminance values:

```
Itot = sum(sum(Image2)) * pixelarea ;
```

The effective luminance is the mean luminance value of all pixels above the luminance threshold of 500 $cd \cdot m^{-2}$:

```
Leff = mean(mean(Image2(Image2 >= 500)));
```

The effective projected area is the product of the pixel area and the sum of all pixels above the luminance threshold:

```
Apeff = sum(sum(Image2 >= 500)) * pixelarea;
```

The new projected area (in m^2) according to Equation (1) follows from

```
Apnew = Itot^2 / ( Leff^2 * Apeff );
```

This "`Apnew`" value is the main result of the measurement and image processing procedure. It represents the value of the projected area of the glare source that does not require any further correction when used to calculate the UGR value because of non-uniformity of the source luminance. Depending on the symmetry of the luminaire, two or four values for "`Apnew`" are determined at the prescribed measurement angles.

5 Determining the luminous source dimensions

The previous clause describes how luminance images are used to derive the projected area of the luminous source as seen from a given viewing direction. In the UGR method (CIE 1995; CIE 2010), the UGR table is determined by the luminous intensity distribution and the dimensions of the luminous source (the dimensions of light emitting parts of the light source). For each viewing direction, the projected area of the luminous source is derived from the source dimensions. The source shape is typically approximated by a basic shape, such as a flat area, a rectangular block, a cylinder, or a sphere. (CIE 1983) and Appendix C of (CIE 1995) describe the relationship between source shape, source area and projected source area. While this shape approximation is still rather arbitrary, the CIE 2019 method limits the choice of dimensions to shapes that have a projected area that is smaller than or equal to the projected area that has been determined from the luminance images. In this clause, only the case of a flat source area and that of a rectangular block are discussed.

For a luminaire with a flat luminous source with area A, the projected area is given by $A_\mathrm{p} = A \cos \gamma$, where γ is the measurement or viewing angle with respect to the geometric axis of the luminaire. When the projected area of the luminous source is determined from the measurement and filtering as described in the previous clauses 3 and 4, the source area is obtained by dividing the projected luminous source area by the projection cosine. Usually, the two or four measurements from different directions result in different values for the luminous source area. Following a worst-case approach, the smallest area is to be used.

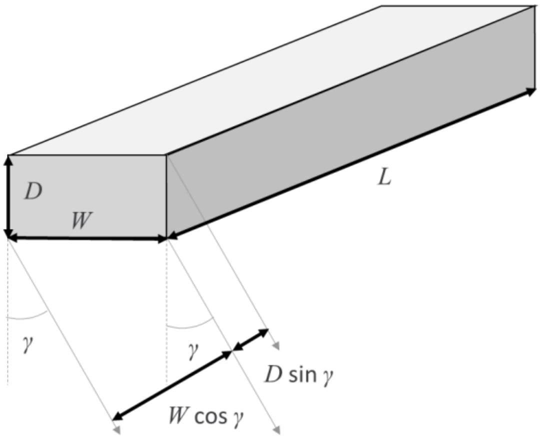
For a luminaire that can be approximated by a rectangular block shape (length L, width W, depth D), the projected area $A_\mathrm{p,C}$ for the crosswise measurement (in the plane perpendicular to the elongated luminaire direction) is given by

$$A_\mathrm{p,C} = L(W \cos \gamma + D \sin \gamma) \qquad (2)$$

where γ is the measurement angle as defined in Figure 2. The projection cosine and projection sine for the different luminous source surfaces are illustrated in Figure 6. Similarly, the projected area $A_\mathrm{p,L}$ for the lengthwise measurement (in the plane parallel to the vertical and the elongated luminaire direction) is given by

$$A_\mathrm{p,L} = W(L \cos \gamma + D \sin \gamma) \qquad (3)$$

In principle, the three dimensions L, W, D can be obtained from the two crosswise and two lengthwise projected area measurements by calculating the inverse of Equations (2) and (3). As in the case of the flat source, the four measurements can result in different solutions to the luminous source dimensions, the smallest of which is to be used.



NOTE The projected lengths are indicated for a crosswise measurement at angle γ with respect to the vertical direction, in the cross-sectional plane perpendicular to the long direction of the source.

Figure 6 – A rectangular block shaped luminous source with dimensions L (length), W (width) and D (depth), as defined in (CIE 1983)

A practical issue that can occur is that the luminance pattern can change at different measurement directions. Consequently, when calculating back, the shape and size of the rectangular block can appear to be different at different viewing angles. The outcome of the inverse calculation can then result in an “averaged” shape and size that deviates a lot from the geometric shape of the luminaire, even though it matches the projected area in the four measurement directions. In case some of the source dimensions are unambiguous (clearly emitting light over the whole length of that dimension), keeping these dimensions fixed helps to avoid such a confusing result. The luminance measurements are then used to determine only the dimensions that are uncertain. This approach will be used in the next clause.

6 Examples of measurement and analysis

The measurement and analysis protocol is illustrated by two examples: a square office lighting luminaire (Figure 7) and a rectangular luminaire for linear lighting systems (Figure 8). The square office lighting luminaire contains two rectangular light emitting windows with a non-uniform luminance distribution caused by the LEDs behind the translucent optical window. In this luminaire, the frame is not emitting light and cannot be part of the glare source. Because of the strong non-uniformity of the optical window luminance, it is not a priori clear whether this full window may be counted as glare source area, even though this is assumed in the photometric data, which use the total area of the two rectangular optical windows combined into a single rectangle: L = 0,566 m, W = 0,234 m, D = 0,000 m (no depth).

NOTE The luminaire contains two rectangular optical windows with a highly non-uniform luminance distribution (not shown in the picture: luminaire is OFF).

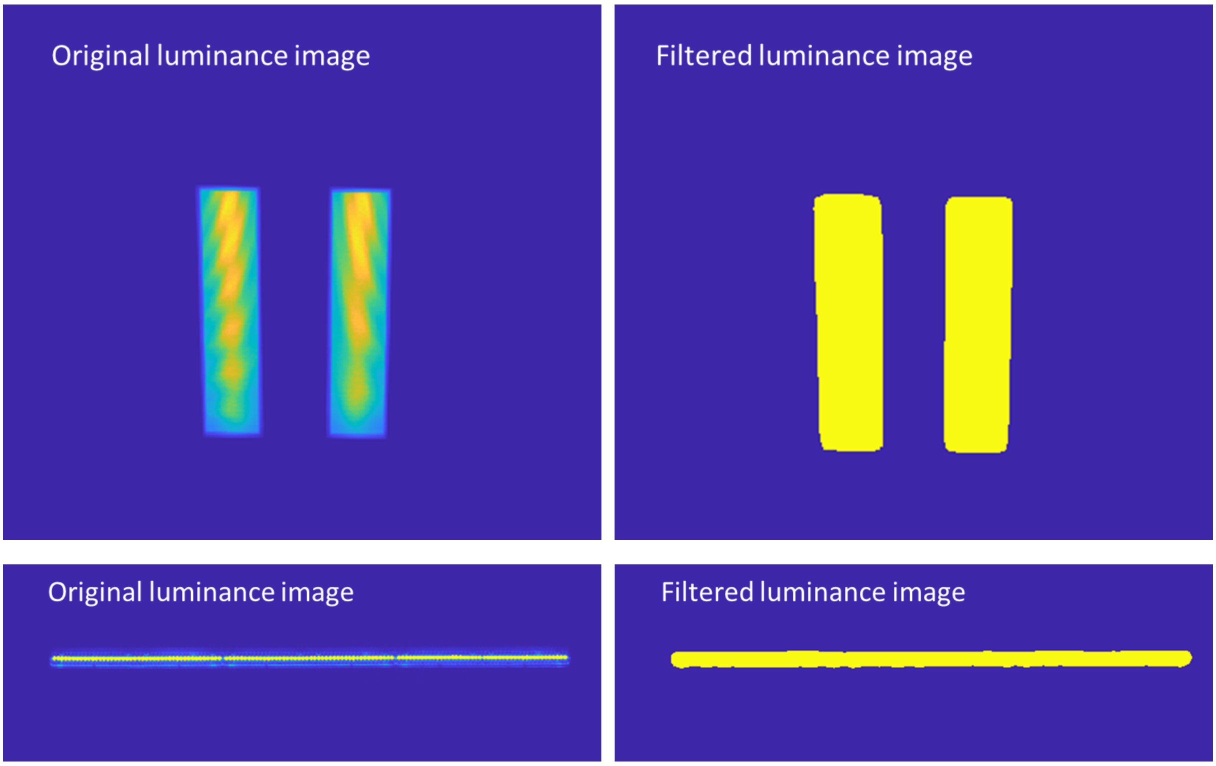
Figure 7 – A square office lighting luminaire

The rectangular luminaire for linear lighting systems contains a single row of LEDs, where each LED has a lens. The lenses are part of a lens plate, which is placed on a white back reflector. The lens, lens plate base, and white back reflector have strong differences in luminance, the lens being the brightest and the white reflector being the dimmest parts. It is not a priori clear whether the glare source area should be defined by the lens area, the lens plate base area, or the full back reflector area. In the photometric data of this luminaire, the source dimensions are chosen equal to the lens plate dimensions: L = 1,706 m (total lens plate length), W = 0,058 m (lens plate width), D = 0,004 m (lens height).

NOTE The luminaire contains a single row of LEDs. Each LED has a beam shaping lens. The lenses are grouped in lens plates on a white back reflector. In the ON state, the lenses are very bright, while the lens plate and the white reflector have a lower brightness.

Figure 8 – A rectangular luminaire for linear lighting applications

In the following, the glare source dimensions of these two luminaires are checked according to the (CIE 2019) method. Luminance images were taken for both luminaires from the four prescribed directions (Clause 2), following the measurement procedure of Clause 3. Measurements for the square office lighting luminaire were taken from a distance of 6,0 m, with a pixel resolution of 0,8214 mm/pixel. The linear luminaire, because of its long length, required a longer measurement distance, which was set at 8,0 m. This resulted in a pixel resolution of 1,0973 mm/pixel (images were taken with the same 25 mm camera lens). Figure 9 shows example luminance images of the original measured images, as well as the images after the processing as described in Clause 4. The processed images show the effective projected area (`Apeff`) with a uniform luminance equal to the effective luminance (`Leff`).



NOTE A linear luminance scale is used, with blue the lowest value and yellow the highest value (different scales in different images).

Figure 9 – Examples of original luminance images (left) and filtered luminance images (right) of the square luminaire (top) and the linear luminaire (bottom)

Table 1 gives the results of the four measurements on the square office luminaire. The third column lists the measured projected area, A_p (called `Apnew` in Clause 4), and the fourth column lists the source area, A (the projected area divided by the projection cosine). Following the worst-case approach, the measured source area is 0,141 m^2. This is slightly larger than the total area of the two optical windows of this luminaire (0,132 m^2). Clearly, the full optical window area may be counted as a glare source area. The slight overestimate is caused by the limited resolution of the method (the 12 mm eye resolution). Even though the method allows for a slightly larger source area (which can be correct from a perception point of view, because a human observer cannot see this difference in size in peripheral view), it is advised to use the mechanical dimensions of the optical window to avoid confusion (as the other parts of the luminaire are clearly non-emitting). In case the measurement resulted in a smaller source area, this smaller area is used (part of the optical window is then insufficiently bright to be considered a source of glare).

Table 2 gives the results of the four measurements on the linear luminaire. The third column lists the measured projected area, A_p (called `Apnew` in Clause 4). Because the luminaire emits light along the full length, L = 1,706 m, and the lens height, D = 0,004 m, is also well defined, both values are used in Equations (2) and (3), leaving only the width, W, to be determined experimentally.

Following the worst-case approach, the smallest width, W = 0,0611 m, which is slightly larger than the lens plate width.[1] Apparently, the lens area and the lens plate area may be counted as glare source area, but most of the white reflector is too dim to be considered as part of the glare source. To avoid confusion, it is advisable here as well to clip down to the nearest mechanical dimension of the luminaire optics (the lens plate width), but it is also plausible here to include a part of the white reflector area. However, the measurement results do not allow the full reflector area to be taken as glare source area.

Table 1 — Measured area of the glare source – square office luminaire

Orientation	Angle γ °	Projected area A_p m^2	Area A m^2
cross	50	0,0909	0,141
length	50	0,0951	0,148
cross	65	0,0610	0,144
length	65	0,0653	0,154

Table 2 — Measured dimensions of the glare source – linear luminaire

Orientation	Angle γ °	Projected area A_p m^2	Width W m
cross	50	0,0723	0,0611
length	50	0,0694	0,0631
cross	65	0,0580	0,0718
length	65	0,0463	0,0639

7 Conclusion

Technical Report CIE 232:2019 provides a supplement to the UGR calculation to determine the source area of a glare source with a non-uniform luminance distribution. This Technical Note gives examples of an HDR luminance image measurement setup, a measurement protocol, and image filters to support luminaire manufacturers and photometric laboratories in determining the glare source area of a luminaire (the method is explicitly not intended for on-site measurements). Several key points in the measurement and analysis are indicated. The projected source area of two different luminaires is determined experimentally. When calculating the source dimensions derived from these measured source areas, it is generally advised to clip down the glare source dimensions to the mechanical dimensions of the luminaire optics as much as possible, to avoid confusing results (many unrealistic combinations of source dimensions can have the same projected area).

References

CIE 1983. CIE 055:1983. *Discomfort glare in the interior working environment*. Vienna: CIE. ISBN: 978 92 9034 055 3.

---

[1] When L, W and D are calculated by inverting Equations (2) and (3), the values L = 1,17 m, W = 0,070 m, and D = 0,022 m are obtained, which clearly do not match the luminaire length and lens height, even though they have the same projected areas as the measured source at the four prescribed angles. This strange shape is caused by the fact that the source height is much smaller than the eye resolution. As mentioned in Clause 5, it is advised to fix the dimensions as much as possible to dimensions of the luminaire optics (parts that are clearly emitting) and use the luminance measurement only to determine the source dimensions that are uncertain.

CIE 1995. CIE 117:1995. *Discomfort Glare in Interior Lighting*. Vienna: CIE. ISBN: 978 3 900734 70 1

CIE 2010. CIE 190:2010. *Calculation and presentation of unified glare rating tables for indoor lighting luminaires*. Vienna: CIE. ISBN: 978 3 901906 87 9.

CIE 2015. CIE S 025:2015. *Test Method for LED Lamps, LED Luminaires and LED Modules.* Vienna: CIE.

CIE 2019. CIE 232:2019. *Discomfort caused by glare from luminaires with a non-uniform source luminance*. Vienna: CIE. https://doi.org/10.25039/TR.232.2019

CIE 2021. CIE 244:2021. *Characterization of Imaging Luminance Measurement Devices (ILMDs)*. Vienna: CIE. https://doi.org/ 10.25039/TR.244.2021

CIE 2023. *TC 2-86 Glare Measurement by Imaging Luminance Measurement Device (ILMD)*. [Online]. [Accessed 13 April 2023]. Available from: https://cie.co.at/technicalcommittees/glare-measurement-imaging-luminance-measurement-device-ilmd

FUNKE, C. 2021. Deutsche Lichttechnische Gesellschaft e.V.: *Praktische Anwendung des korrigierten UGR-Verfahrens nach CIE 232:2019*, Licht2021 Tagungsband, LiTG: Berlin, 2021. ISBN 978-3-927787-98-8