ANSI E1.35 – 2013 (R2018)

Lens Quality Measurements for Pattern Projecting Luminaires Intended for Entertainment Use

Photo/2006-5010r5

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1.0 Scope

This standard is intended to be used for the measurement and presentation of data reporting the contrast, perceived image quality (sharpness), and distortion of lenses used in pattern projecting luminaires for the entertainment and performance industries. This standard defines a methodology for measuring and a format for presenting this data to be presented on documents purporting to accurately describe the performance of these lenses. It does not prohibit the presentation of information in addition to that required by this standard.

2.0 Definitions

For the purposes of this standard, the following terms shall be defined as:

2.1 focusing range: The range of throw distances in which a hard focus can be projected by the luminaire.

2.2 far-field luminaire: A luminaire whose intended operating distance from the subject is greater or equal to the distance at which the inverse-square law can be used to predict an illumination level.

2.3 gate size: The diameter of the aperture at the object plane such that the output field angle equals the rated field angle of the luminaire/lens combination.

2.4 hard focus: A focus position that achieves the most clearly defined edge to the illuminated area. Because of field curvature, this typically requires a best compromise between the beam center and edge.

2.5 illuminance: The areal density of the luminous flux incident at a point on a surface.

2.6 light beam: The light emitted from the exit aperture of a luminaire.

2.7 luminaire: A complete lighting unit, consisting of a lamp or lamps, together with all the parts that are needed to position and protect the lamp or lamps, distribute the light, and connect the lamp or lamps to the power supply.

2.8 near-field luminaire: A luminaire whose intended operating distance from the subject is shorter than the minimum distance at which the inverse-square law can be used to predict an illumination level.

2.9 throw distance: The distance between the exit aperture of the luminaire and the surface being illuminated.

2.10 variable angle luminaire: A luminaire that has optical elements designed to be adjusted to vary the total area illuminated at a given throw distance.

3.0 Requirements

Lens quality data reports for all types of luminaires shall include the following information.

Numerical values shall be expressed with sufficient numbers of significant digits to accurately represent the information without implying a greater precision than was present in the original lens quality data.

3.1 Organization responsible for the product

The manufacturer's name, trademark, or other descriptive marking identifying the name of the organization that is responsible for the product shall be provided.

3.2 Catalog number, model number, or name of luminaire and lens
The catalog number, model number, name, or other unambiguous identifier for both the luminaire and lens shall be noted.

3.3 Lamp used for gathering photometric data
The lamp or lamps used to gather the reported lens quality data shall be specified in an unambiguous manner.

3.4 Photometric procedure
A brief statement shall be provided to describe how the data was gathered. If any nationally or internationally recognized standard or recommended practice for measuring lens quality was used, it shall be cited. The date and laboratory where the tests were performed shall be noted.

3.5 Marking of conformance with this standard
Luminaire performance data sheets that conform to this standard shall be marked "Data sheet conforms to American National Standard E1.35 -XXXX" with XXXX being replaced by the year of the edition of the E1.35 standard used.

4.0 Test Methods

4.1 Test equipment

4.1.1 Test pattern description

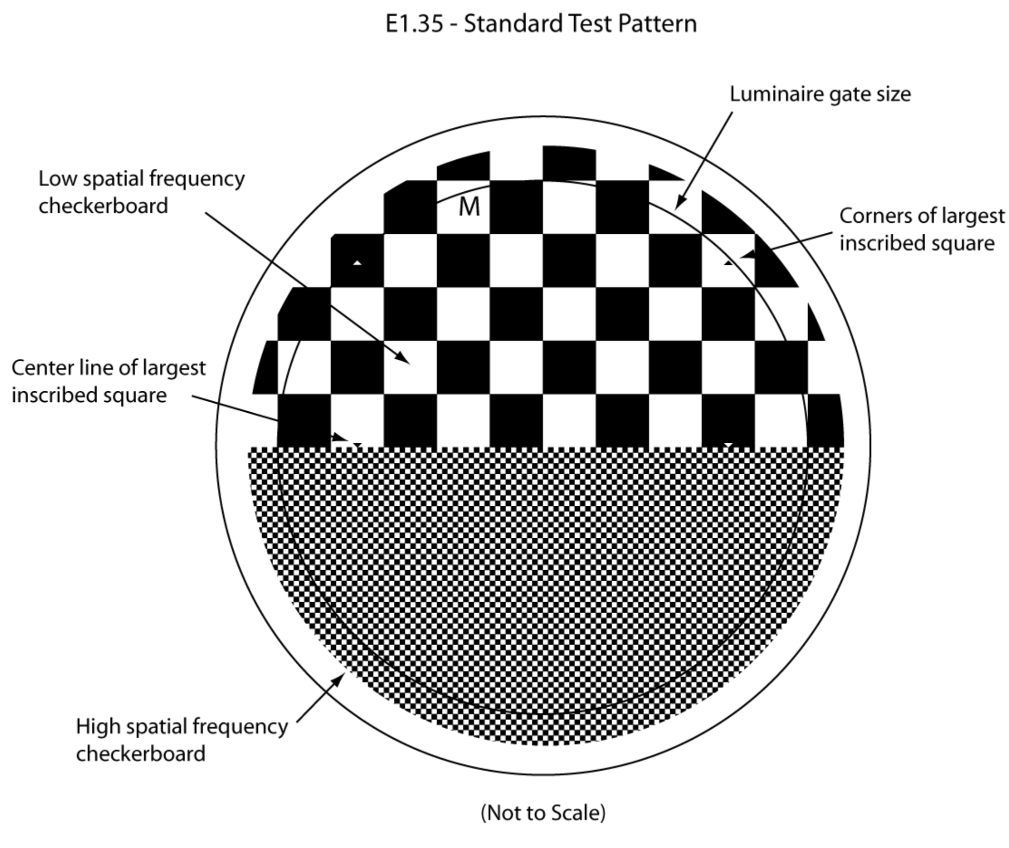

Figure 1 – Test Pattern

The test pattern (gobo) shall be as shown in Figure 1. There are five main elements to the pattern:

a. A low spatial frequency checkerboard with a period of 20% of the gate size covering 50% of the luminaire gate. (10 alternating black and white squares across the gate size)

b. A high spatial frequency checkerboard with a period of 2% of the gate size covering 50% of the luminaire gate. (100 alternating black and white squares across the gate size)

c. A circle at the specified luminaire gate size

d. Marks indicating the corners and center line of the largest square than can be inscribed within the gate size.

e. The pattern is a flat plane.

Further descriptive marks or designations may be added to the pattern such as the 'M' designation shown in Figure 1. Such marks and designations do not form part of this standard.

> *Informative note: Figure 1 illustrates an 'M' size pattern. Similar but scaled patterns can be created for common gate sizes such as 'M', 'B' and, 'A' as well as any custom size desired. The critical design dimensions in every case being that the two checkerboards have periods that are 20% and 2% of the quoted gate size.*

4.1.2 Manufacture of the test pattern

The test pattern can be manufactured in any suitable material by any suitable process that ensures it remains flat and dimensionally stable, and that the image is accurate. It shall have the following optical qualities for the visible light range of 400-700 nm:

a. The opaque areas of the test pattern (shown black in Figure 1) shall have a transmittance less than or equal to 0.1%.

b. The clear areas of the test pattern (shown white in Figure 1) shall have a transmittance greater than or equal to 90%.

c. The face of the test pattern opposite the light source shall have a reflectance less than or equal to 12%.

4.1.3 Test surface

The image shall be projected onto a test surface for measurement. The test surface shall be flat and perpendicular to the optical axis of the luminaire. The test surface shall be positioned at a throw distance within the focusing range of the luminaire.

4.1.4 Illuminance meter

The illuminance meter shall be capable of handling the dynamic ranges encountered in the test procedures described in 4.2 without switching measurement ranges. The effective sensor area shall have no dimension (e.g., length, width, diameter) that is greater than one half the width of the smallest square to be measured on the test pattern checkerboard.

4.2 Test procedure

4.2.1 Test setup

The test pattern as defined in 4.1.1 and 4.1.2 is inserted in the luminaire gate for projection.

The lamp output shall be maintained at a steady value for the duration of the test.

The image shall be projected onto the test surface as defined in 4.1.3. The throw distance from the luminaire to the test surface shall be recorded.

The luminaire and lens shall be adjusted so that the image is in hard focus.

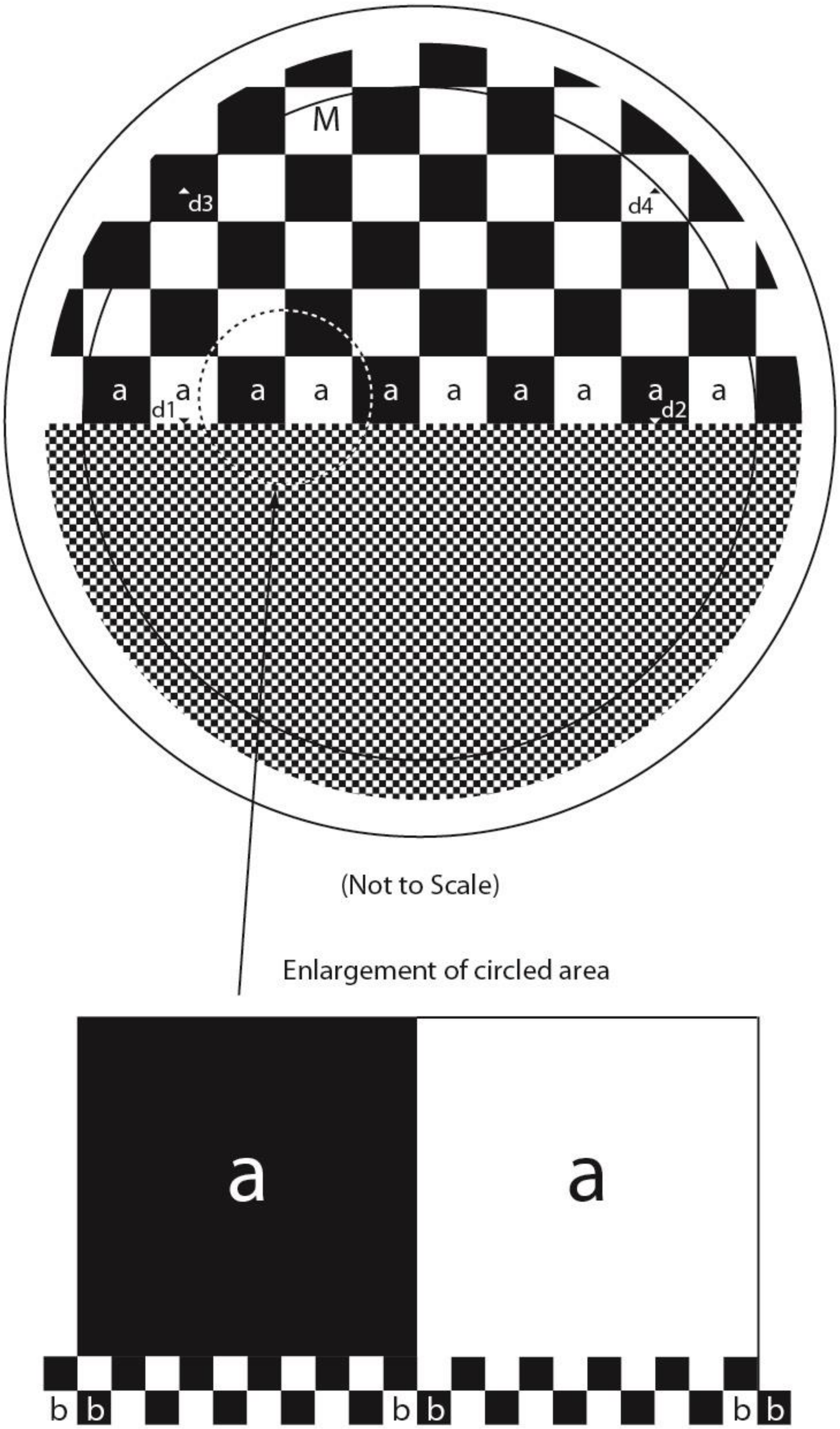

Figure 2 – Measurement Positions

4.2.2 Contrast ratio measurement

Measurements of illuminance shall be taken at the center of the ten squares (marked ‘a’ in figure 2) either side of the nine transitions in the low spatial frequency portion of the projected pattern. These measurements shall be taken in the squares adjacent to the diameter of the beam.

For each of the nine transitions a Modulation percentage figure shall be calculated as:

$$\mathbf{Modulation_C = ((I_{max} - I_{min}) / (I_{max} + I_{min})) \times 100\%}$$

Where I_{max} and I_{min} are the maximum and minimum illuminance measured on either side of the transition.

The nine calculated values for **$Modulation_C$** shall be averaged and reported as the **Contrast Modulation** percentage for the tested luminaire/lens combination.

4.2.3 Sharpness measurement

Measurements of illuminance shall be taken at the center of eighteen squares (marked ‘b’ in figure 2) arranged as nine adjacent pairs distributed evenly in the high spatial frequency portion of the projected pattern. These measurements shall be taken in the row of squares that is one row away from the diameter of the beam. The pairs of squares measured shall be the squares in that row which are closest to the transitions in the low spatial frequency portion of the projected pattern.

For each of the nine transitions a Modulation percentage figure shall be calculated as:

$$\mathbf{Modulation_S = ((I_{max} - I_{min}) / (I_{max} + I_{min})) \times 100\%}$$

Where I_{max} and I_{min} are the maximum and minimum illuminance measured on either side of the transition.

The nine calculated values for **$Modulation_s$** shall be averaged and reported as the **Sharpness** percentage for the tested luminaire/lens combination.

4.2.4 Barrel/Pincushion distortion measurement

The distances between the marks d_1 & d_2 and d_3 & d_4 shall be measured on the test surface.

The distortion shall be calculated and reported as follows:

$$\mathbf{Distortion = ((Distance_{(d_3 d_4)} - (Distance_{(d_1 d_2)})) / (Distance_{(d_1 d_2)}))) \times 100\ \%}$$

Informative note: A positive value indicates pincushion distortion, and a negative value indicates barrel distortion.

Appendix A

This appendix is informational only, and is not part of the requirements of this Standard. If there is any apparent disagreement between the information in this appendix and the requirements stated in this Standard, the requirements of this Standard shall prevail.

The Problem

There are established methods of measuring and presenting the performance of high quality projection lenses through MTF (Modulation Transfer Function) measurements. However these techniques and the associated presentation of the data are not appropriate for the quality of lens commonly used in theatrical pattern projection luminaires such as ellipsoidal reflector spotlights.

The lenses used in theatrical pattern projectors are normally of significantly lower quality than projection lenses and the presentation of MTF data is not something the majority of users of this equipment would find useful. In addition the measurement of MTF can require specialist equipment not commonly available. Finally MTF is by definition assumed to be unity at low frequencies. That’s a reasonable assumption with high quality lenses but ignores the substantial stray light issues with common theatrical lenses and the associated reduction in image contrast and sharpness.

This standard therefore has two components:

1. A method for measuring lens quality with particular emphasis on contrast, perceived image quality (sharpness) and distortion.

2. A method for presenting these results on a datasheet in a format that is readily understood by a typical end user and that allows the end user to directly compare lenses in a meaningful way.

Background

If we examine the projection of test patterns from gobos we can clearly see the differences in focus quality between different lenses.

Figures A1-A3 on the following page shows examples of the images from 3 lenses. It is clear that Lens C is the best followed by Lens B and finally lens A.

However, how much better and how do we enumerate it?

There are two significant and measurable differences between the images shown in Figures A1-A3.

1. The Contrast Ratio of the image. It is clear that Lens C has excellent crisp blacks and whites whereas A has a ‘bloomed’ look with stray light reducing the contrast ratio.

Measuring the contrast ratio alone doesn’t do it. Lens C and Lens B have very similar contrast ratios even though it is obvious to the eye that Lens C is better.

2. The difference is in the slope or sharpness of the edges; that is the slope of the transitions in an illuminance versus position graph. Lens C has very steep sides to its edges while Lenses A & B have sloping edges indicating a softer focus.

Figures A1-A3 also show line profiles across the center portion of the image field for these same three lenses where you can clearly see both contrast and slope/sharpness differences between the lenses.

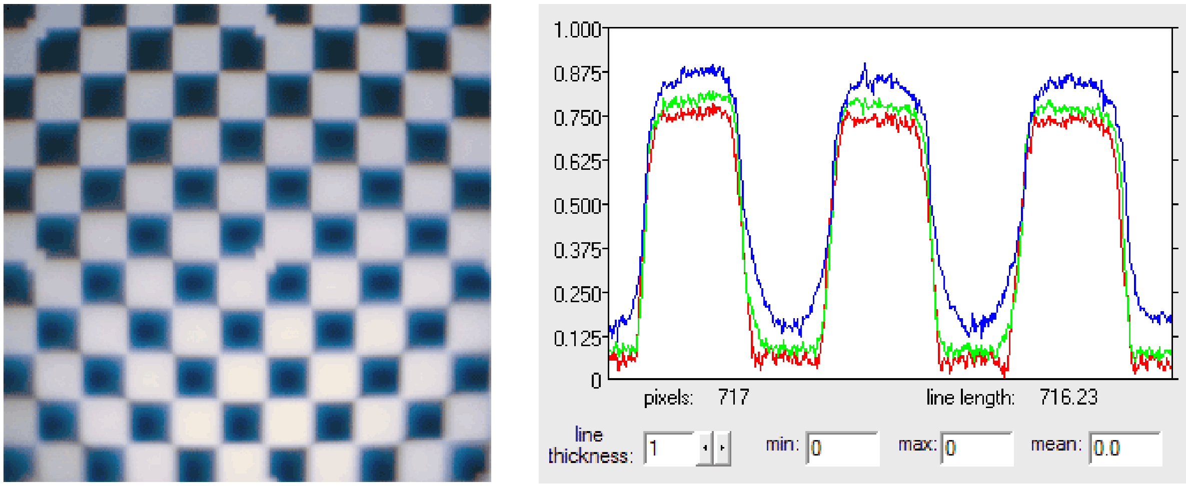

Figure A1: Lens A

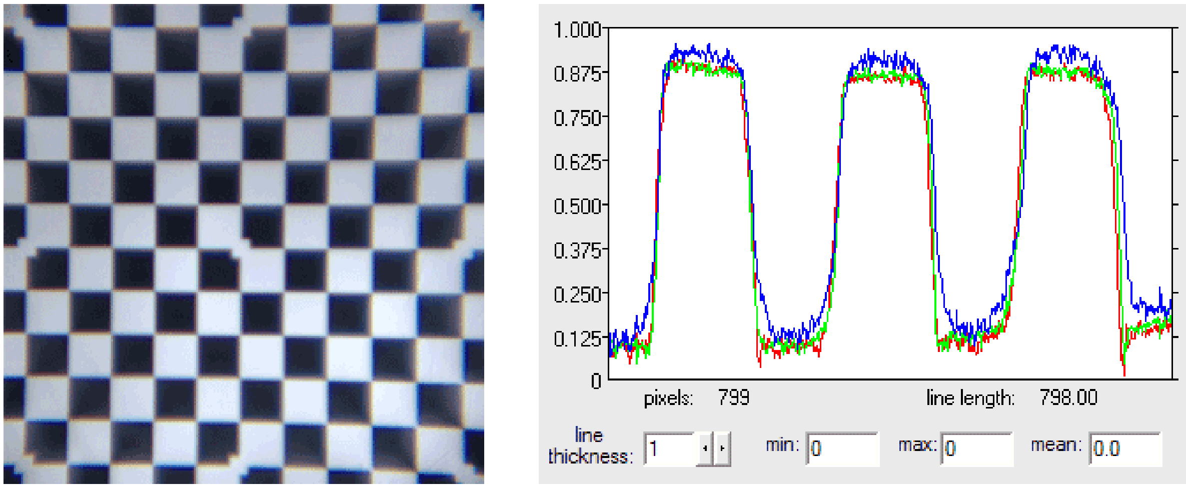

Figure A2: Lens B

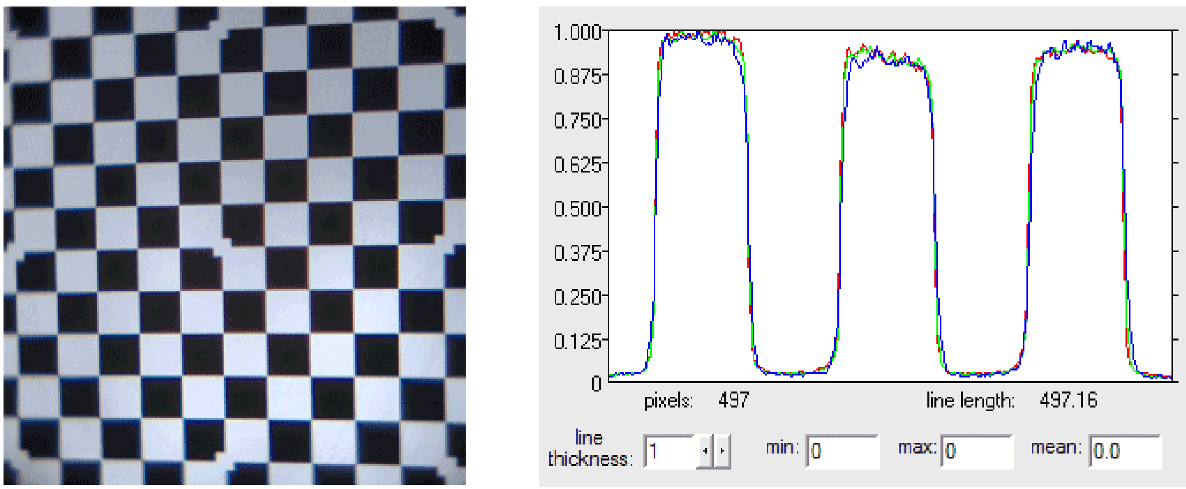

Figure A3: Lens C

If we zoom in and focus on a single white/black transition using the combined Illuminance signal then this slope difference is very easy to see:

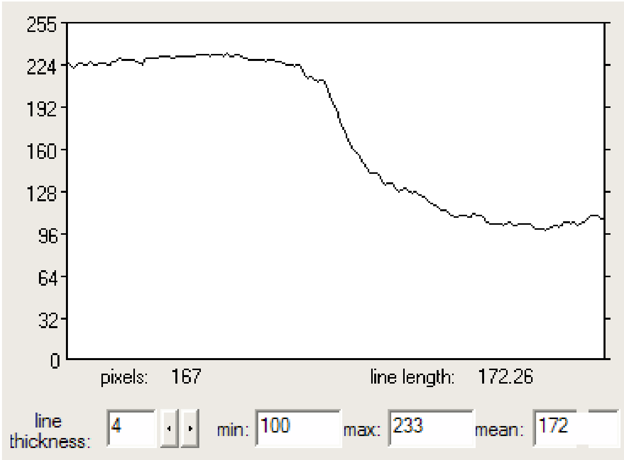

Figure A4: Lens A

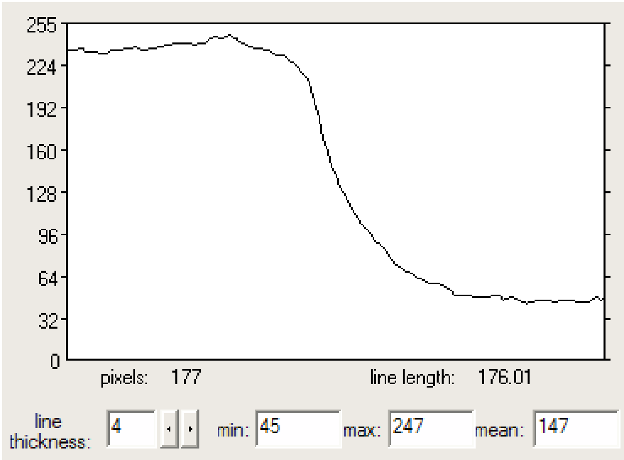

Figure A5: Lens B

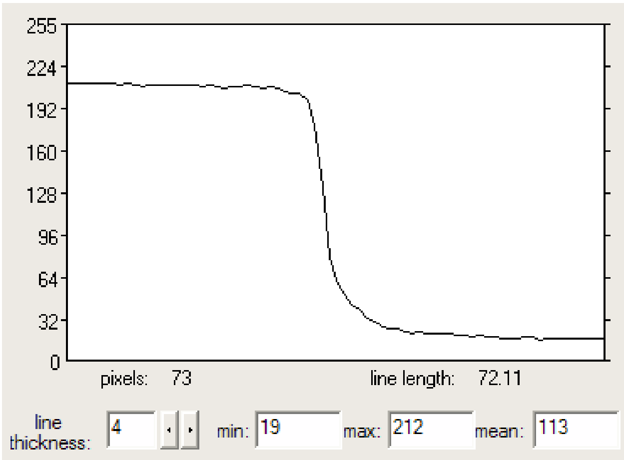

Figure A6: Lens C

Measurement Procedure

The contrast ratio is relatively simple to measure; we can define a checkerboard gobo with a standardized number of 'checkers' or black/white transitions across the field. By choosing a small number of transitions, 10, we can ensure that the contrast ratio is measured at a low spatial frequency well within the pass band of the lens. This low frequency grid with 10 squares across the field is as illustrated in the top half of Figure 1.

Measuring the edge slope or sharpness is potentially more difficult. Measurements could be taken off line scans such as those shown in Figures A4, A5 & A6 but such measurements are likely to be subjective and difficult to repeat.

Instead we again measure the excursion from high to low illuminance, but this time of a higher spatial frequency checker board, one with 100 squares across the field, as illustrated in the lower half of Figure 1.

Figure A7 illustrates the principle. The coarse grid (top half of Fig 1) has a period of 20% of the field width so that we are measuring the very low spatial frequency (almost DC) contrast ratio.

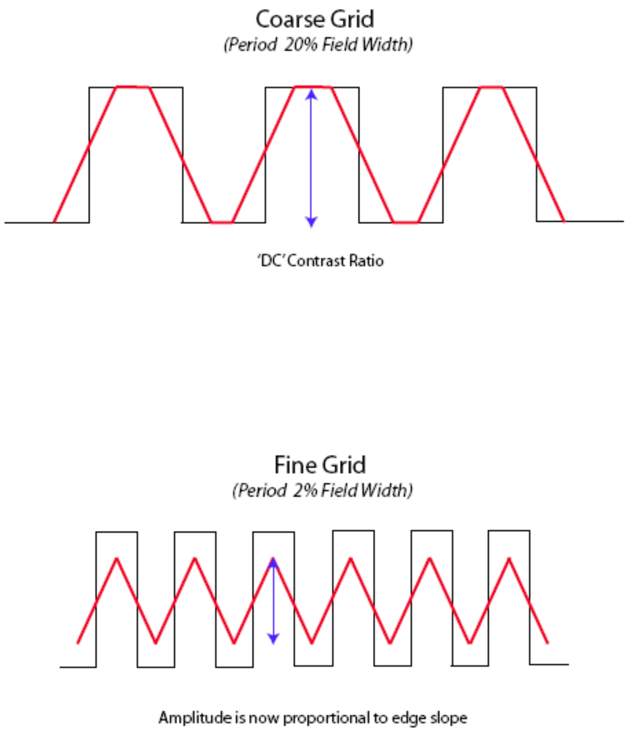

Figure A7

As we increase the spatial frequency to a finer grid checkerboard chosen to have a period that is finer than the width of the edge slope (2% of field width) the resultant image will never reach the full extents of the 'low frequency' image. (see Figure A7: Fine Grid). The theoretical projected image (red line in each case) will be a roughly triangular wave whose height is directly proportional to the slope of its sides; i.e. proportional to the edge slope. So now both measurements can be taken by measuring simple illuminance levels. (This is a simplification of the physics and assumes that the edges will be straight lines, in reality these are curves of course. However this assumption is reasonable for this type of lens and yields good comparative figures)

Note: The 2% figure has been chosen after taking measurements of many different lenses using this technique, in every case a 2% grid was neither so coarse that it gave a figure similar to the Low Frequency grid nor so fine that a poor lens could only reproduce a flat grey field. Every lens tested produced a meaningful result with a 2% grid (100 squares)

For a waveform with maximum and minimum Illuminance of I_{max} and I_{min} respectively it is usual to express these figures not as a straight contrast ratio of I_{max}/I_{min} but as a normalized Modulation percentage figure, so we have:

$$\textbf{Modulation} = ((I_{max} - I_{min}) / (I_{max} + I_{min})) \times 100\ \%$$

Modulation values always lie between zero and one and can conveniently be expressed as a percentage as here.

Verification of the Procedure

Figures A8 and A9 illustrate line scans across a lens projecting a gobo as illustrated in Figure 1 showing the 20% and 2% checkerboards respectively. It is clear that the amplitude has reduced as predicted by Figure A7.

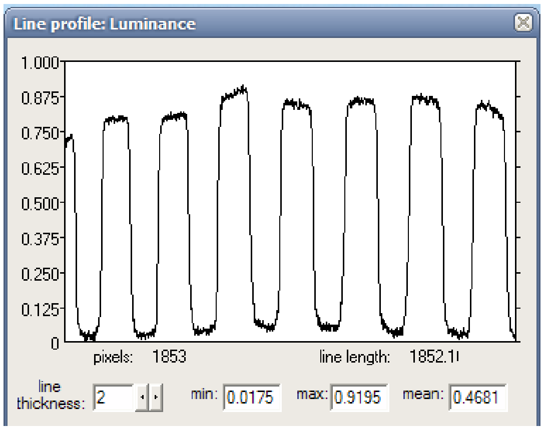

Figure A8: Line scan with 20% checkerboard
Lens D, Contrast Modulation = 94%

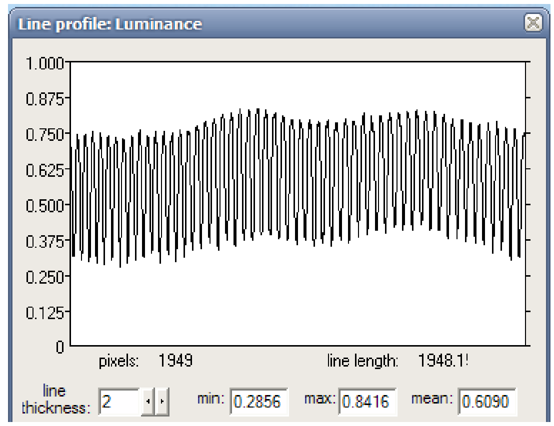

Figure A9: Line scan with 2% checkerboard
Lens D, Sharpness = 37%

Figures A10 and A11 show the same data but for a poorer quality lens, the amplitude with the 2% checkerboard is decreased further.

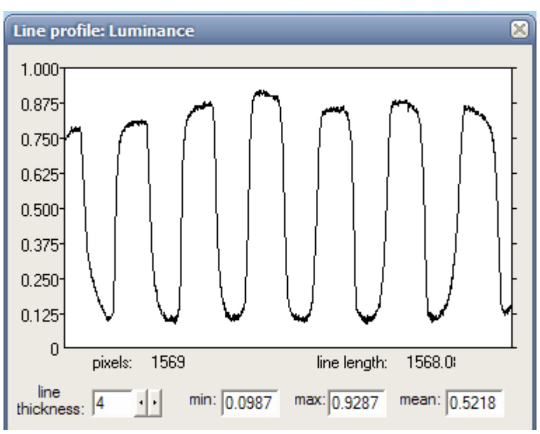

Figure A10: Line scan with 20% checkerboard
Lens E Contrast Modulation = 78%

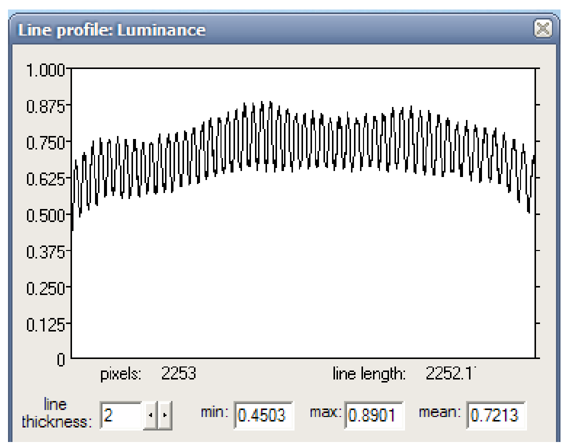

Figure A11: Line scan with 2% checkerboard
Lens E, Sharpness = 17%

