IrisGuard Company Confidential *Reference**:** Lucid 2009/08/IrisGuard/01*

Lamp Standard Classification of an IrisGuard AD100 LED Device

for

IrisGuard

Prof. Geoff R Davies
Lucid Optical Services Ltd.
Lucid Training Centre,
Garsdale, Sedbergh,
Cumbria LA10 5PE
UK

4th August 2009

Printed in U.K. by Lucid Optical Services Ltd.

Illustrations courtesy of Lucid Optical Services Ltd.

Lamp Standard Classification of an IrisGuard AD100 LED Device

Prepared by:

Prof. Geoff R. Davies,
Lucid Optical Services Ltd.
Lucid Training Centre,
Garsdale, Sedbergh,
Cumbria LA10 5PE

Tel: +44 (0)15396 21219
Fax: +44 (0)15396 21205
email: Geoff@LucidOS.co.uk

Date: 4th August 2009

CONTENTS

1. Executive Summary

The aim of this investigation was to classify the IrisGuard LED device according to CIE S 009/E:2002 prepared by the International Commission on Illumination (CIE) as a general standard for lamps and luminaries.

The device spectrum was measured and found to peak at 819 nm with a full width half maximum (FWHM) of 37 nm. Essentially all of its output lies at wavelengths longer than 740 nm.

In view of these output characteristics we need not consider the Actinic UV hazard, the Near-UV hazard nor the Blue Light Hazard.

The major potential hazard is the retinal thermal hazard since a weak irradiance at the surface of the eye can be increased enormously when it is focussed on the retina. For safety, however, we have also considered the infrared non-retinal eye hazard. (Simply by placing your hand in front of the device when it in operation it is clear that we need not consider the skin burn hazard!)

The retinal thermal hazard is characterised by radiance measurements (power per unit area per unit solid angle) and requires a knowledge of the source subtense angle (the apparent source size / distance). Digital photography shows that the true source profile is extremely complex but we have assumed a worst case model where all the measured output is assumed to arise from the chip image which we estimate to be 1.4 mm x 1.4 mm and assume is located close to the physical chip itself.

We have considered a number of cases with different limits and calculations as summarised below. The safety factor, SF, listed below is the ratio of the limit for the test divided by the measurement. In all cases the limit applies to the Exempt Group.

Hazard	**Limit**	**Measurement**	**SF**
Retinal thermal hazard	4.02 MW/m^2/sr	31 kW/m^2/sr.	130
weak visual stimulus 1	857 kW/m^2/sr	31 kW/m^2/sr	28
weak visual stimulus 2	108 kW/m^2/sr	912 W/m^2/sr	118
Full source	505 kW/m^2/sr	2.52 kW/m^2/sr	200
non-retinal infrared	3.2 kW//m^2	10.5 W/m^2	305

In the light of the above safety factors, we are confident that this device falls into the Exempt Group as defined according to the CIE S 009/E:2002 or IEC 62471 Edition 1: 2006 standards and poses no photobiological hazards.

(N.B. we have not confirmed that the optical output of the device conforms to a weak visual stimulus category since it falls into the Exempt Group irrespective of this).

2. Introductory Remarks

The aim of this investigation was to classify the IrisGuard LED device according to CIE S 009/E:2002 prepared by the International Commission on Illumination (CIE) as a general standard for lamps and luminaries. It covers all electrically powered incoherent broadband sources of optical radiation, including LEDs but excluding lasers, in the wavelength range from 200 nm to 3000 nm.

It has also been issued as a duplicate International Electrotechnical Commission (IEC) standard (IEC 62471 Edition 1: 2006) and is now the main European standard for LEDs.

Four classification groups are defined:

- The Exempt Group (no risk)
- Risk Group 1 (Low-Risk)
- Risk Group 2 (Medium-Risk)
- Risk Group 3 (High-Risk)

The difference between these groups is basically the time for which one could be exposed to the output radiation without harm.

This standard does not give much advice on appropriate control measures and, in particular, does not yet specify any labelling requirements though it may do so in a forthcoming revision.

Since many people are used to classifying LEDs according to BS EN 60825-1, we make comparisons with such classifications even though the current standard has removed LEDs from its scope. (Note also that the 'User Guide' in the old BS EN 60825-1 is now BS EN 60825-14 which should be seen as the primary document for laser users. The information in BS EN 60825-1 is now primarily for manufacturers.)

Measurements made were sufficiently accurate for the purpose of Lamp Group assignment. Data were obtained by approximate methods and 'worst case' analyses were followed where uncertainties arose. Comparisons between measured data and computed limits were sufficiently clear that highly accurate measurements were not required.

2.1. Spectral Analysis

The spectrum of the device was measured using one bank of 6 LEDs. The output peaked at 819 nm with half power points at 798 nm and 835 nm. The full spectrum is shown in Figure 1 below:

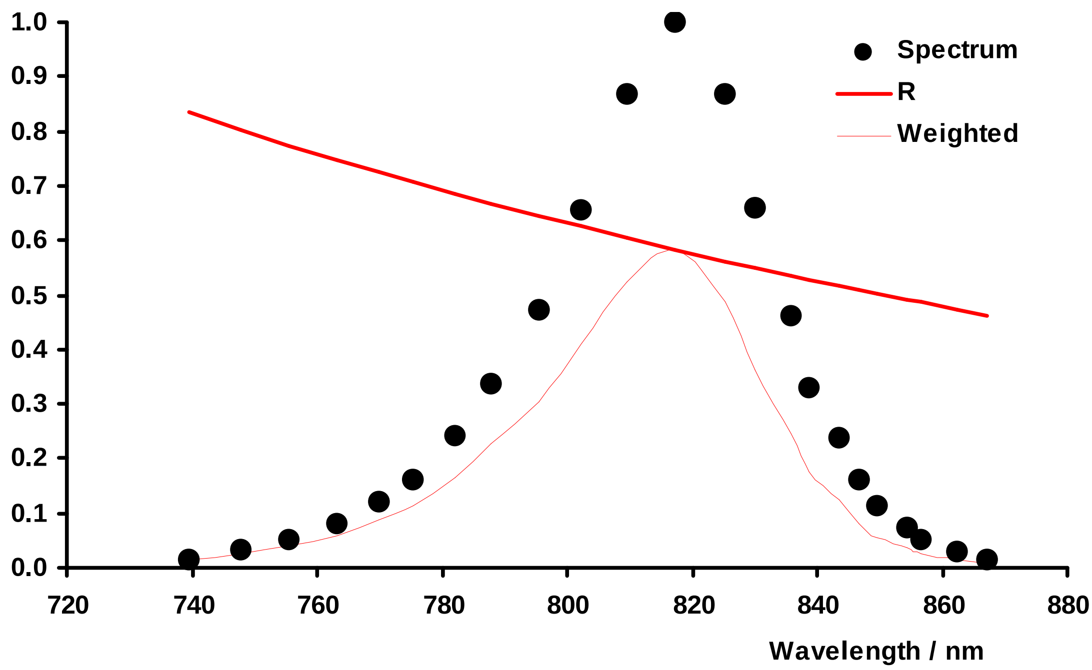


Figure 1: The device spectrum and the thermal hazard action spectrum, R

The spectral width (full width at half height) is thus 37 nm though, as is apparent from the plot above, there is a slight asymmetry, the higher half-width being 16 nm and the lower 21 nm.

2.2. Irradiance measurements

Irradiance measurements were made primarily at 200 mm from the LEDs since this was taken as a 'worst case' closest approach distance. A black surface was first illuminated by 6 LEDs and the illuminated area was viewed through an infrared-sensitive webcam.

The illuminated area was found to be roughly 100 mm in diameter but two or three 'hot spots' ~ 20 mm x 40 mm were apparent within this area. Measurements made within the hot spots (using an 8 mm diameter detector) yielded a maximum power of 530 μW or an irradiance of 10.5 W/m^2.

The small-source 60825-14 100 s MPE value is 17.3 W/m^2 for 819 nm. It falls with decreasing wavelength, however. being only 12 W/m^2 for 740 nm. The device output at this wavelength is less than 2% of the peak output, however, hence the device is eye- safe to 60825 standards (not currently applicable to LED devices).

This small source analysis is a worst-case analysis since it assumes that all of the measured power can be imaged to a single diffraction and aberration-limited spot on the retina. In fact, the six LEDs are on a 6.5 mm grid and hence each will form their own retinal image at an angular separation of 32.5 mrad.

If all LEDs contributed equally to our measurement we could divide the measured power by 6 to estimate the hazard from a single LED. Since it was deemed unlikely that this assumption was valid we masked off all but one LED and measured its output at 200 mm. On checking the background measurement, It was found necessary to also mask off the visible emitters on the front panel of the device.

Viewing an illuminated screen via the web-cam still yielded an unevenly illuminated field with obvious hot spots. The maximum power measured in a hot spot was found to be 85 μW.

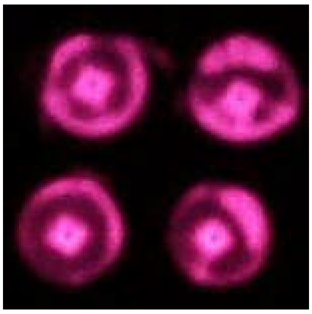
This is less than one sixth of the previous measurement and hence we might conclude that other LEDs contributed more to our previous measurement. Our 6 LED measurement did not have the front panel visible emitters screened off, however, so a more likely explanation is that a background of about 30 μW or more should be subtracted from the 6 LED measurement. We have not performed this background check, however, since all subsequent analysis is based upon the single LED measurement.

In reality, there will be variation in the LEDs from batch to batch so we suggest taking 100 μW as an estimate of the output from a more powerful LED.

2.3. Source Subtense Angle

The apparent source subtense angle is extremely difficult to measure accurately. We photographed the LEDs using a digital camera and obtained the pictures shown below:

LEDS off



LEDs on

An image of the LED chips can be seen in both pictures but the apparent source shape is extremely complex. As a worst case analysis we have assumed that all of the output comes from the central square. Given that the LEDs are separated by 6.5 mm, we estimate the apparent side of this emitting square to be 1.4 mm. This is reasonable since the physical chip is almost certainly a 1 mm square chip.

At 200 mm the subtense angle would therefore be 7 mrad giving a 60825 C_6 factor of 4.67 and raising the 100 second exposure MPE to 79 W/m^2 making our 60825 'eye-safe' assertion even more valid.

3. Lamp Safety Analysis

CIE S 009/E:2002 introduces the concept of Lamp Groups rather than Laser Classes and a number of different hazards, most of which are described by a 'hazard function' or an 'action spectrum' which characterises the degree to which any given wavelength might contribute to the hazard in question.

In view of the output characteristics of the device which is essentially limited to the infrared bands, we need not consider the Actinic UV hazard, the Near-UV hazard nor the Blue Light Hazard.

For a relatively weak near infrared source the major hazard is the retinal thermal hazard since a weak irradiance at the surface of the eye can be increased enormously when it is focussed on the retina. For safety, however, we also consider the infrared non-retinal eye hazard.

Simply by placing your hand in front of the device when in operation it is clear that we need not consider the skin burn hazard.

3.1. The Retinal Thermal Hazard

The retinal thermal hazard should be assessed using the average source spectral ***radiance*** , L_λ , (power per unit area per unit solid angle per unit wavelength) averaged over a specified field of view, γ, which varies with time. For times less than 0.25 s $\gamma = \gamma_{min}$ = 1.7 mrad. At 10 s γ = 11 mrad. At intermediate times $\gamma = \gamma_{min} (t/0.25)^{0.5}$.

The key time for the lower Lamp Group classifications is 10 s, hence we need only consider γ = 11 mrad. This field of view will enclose all of the chip area of a single LED but will not enclose 2 chips (angular separation 32.5 mrad). We need therefore consider only a single LED.

Note that the average spectral radiance, L_λ is calculated using the field of view solid angle, not the actual sold angle of the source. Averaging over this larger field of view results in a smaller radiance,

The risk is assessed using the burn hazard function R(λ) to weight the average spectral radiance to obtain an effective radiance, L_R. (The burn hazard function, R, for the retinal thermal hazard is shown in Figure 1 as the thicker red line and the product L_λ R(λ) is shown as the thin red curve.)

$$L_R = \sum_{380}^{1400} L_\lambda R(\lambda)\Delta\lambda$$

For the Exempt Group and Lamp Group 1,

$$L_R \le \frac{50000}{\alpha t^{0.25}} \quad W/m^2/sr$$

where α is the source subtense angle (7 mrad) and t is 10 s.

The 10 s limit is thus **4.02 MW/m²/sr** which is more than two orders of magnitude greater than our computed effective radiance of **31 kW/m²/sr**. We can therefore be confident that, on the basis of the Retinal Thermal Hazard, the device should be classified no higher than Lamp Group 1.

The choice between Exempt Group and Lamp Group 1 must be made on the basis of the Weak Visual Stimulus analysis.

3.2. The Retinal Thermal Hazard (weak visual stimulus)

This analysis uses essentially the same effective average radiance definition (but limited to the range 780 - 1400 nm). It is only for weak visible sources and times greater than 10 s. (We have not confirmed that this device is a weak visual source since this requires luminance measurements.)

The limit is 6000/α kW/m^2/sr evaluated at 1000 s.

The field of view is specified as not less than 11 mrad and not more than 100 mrad.

Taking the 11 mrad case first, we find that one LED of subtense angle 7 mrad yields a limit of **857 kW/m^2/sr**. The calculation we have already made of the effective radiance of **31 kW/m^2/sr** is clearly less than this limit even though it has a small contribution from wavelengths outside the defined range.

For 100 mrad acceptance angle we would see all six led chips in a roughly rectangular array of maximum dimensions 7.9 x 14.4 mm giving a subtense angle of 55.7 mrad and a limit of **107.7 kW/m^2/sr**. (We ignore the complication that the array is not strictly rectangular).

Naively we might compare this with 6 x 31 kW/m^2/sr (i.e. 6 x single led radiance) and conclude that the limit is exceeded. This is wrong, however, since we now must evaluate the average radiance of the much larger solid angle corresponding to a 100 mrad acceptance angle. The average effective irradiance for all 6 leds is **912 W/m^2/sr**. This is again safely less than the limit of107.7 kW/m^2/sr and hence the device falls into the Exempt Group on this analysis. It is therefore irrelevant whether or not it falls into the weak visual source category.

3.3. Retinal Thermal Hazard, Full Source Analysis

Note 2 to the retinal thermal hazard exposure limit states that the analysis of section 3.1 should also be applied 'to the source as a whole when the average radiance over the full source is used'.

Taking the same array of 6 LED chips used above as the whole source, α is 55.7 mrad leading to a limit of **505 kW/m^2/sr.** Using a source area of 7.9 x 14.4 mm we calculate an average effective radiance of **2.52 kW/m^2/sr** which is again safely below the limit.

3.4. IR radiation hazard for the eye, non-retinal

For non-retinal eye infrared exposure there are simple irradiance criteria. For the Exempt Group the limit is 18000 $t^{-0.75}$ W/m^2 where t is 1000 s. This yields a limit of **3.2 kW//m^2**

The maximum measured irradiance for all 6 LEDs was **10.5 W/m^2** and hence under this criterion also, the device falls into the Exempt Group.

4. Conclusions

We are confident that this device falls into the Exempt Group as defined according to the CIE S 009/E:2002 or IEC 62471 Edition 1: 2006 standards and poses no photobiological hazards.