



Photobiological Safety: Lighting Applications with IDR300-PSL

Measurement Procedure

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Contents

1. Introduction	3
2. PSL Wizard – Lighting Applications	3
3. Specific UV Hazard (IEC 61167, IEC 60598-1)	4
3.1 Applicability	4
3.2 Hardware Setup	4
3.3 Software Setup	4
3.4 Calibration Measurement	5
3.5 Applying Calibration	5
3.6 Source Measurements	6
4. IEC TR 62778	7
4.1 Overview	7
4.2 Determination of Source Size with a Ruler	7
4.3 Determination of Source Size with the PSL Profiler	8
4.4.1 Sources subtending <11mrad- Blue Light Irradiance Measurement	10
5.4.2 Hardware Setup	10
5.4.3 Software Setup	10
5.4.4 Calibration Measurement	11
5.4.5 Applying Calibration	11
5.4.6 Source Measurements	11
5.5.1 Sources >11mrad, Blue Light Radiance Measurement	12
5.5.2 Hardware Setup	12
5.5.3 Software Setup	12
5.5.4 Calibration Measurement	12
8.4 Applying Calibration	13
8.5 Source Measurements	14

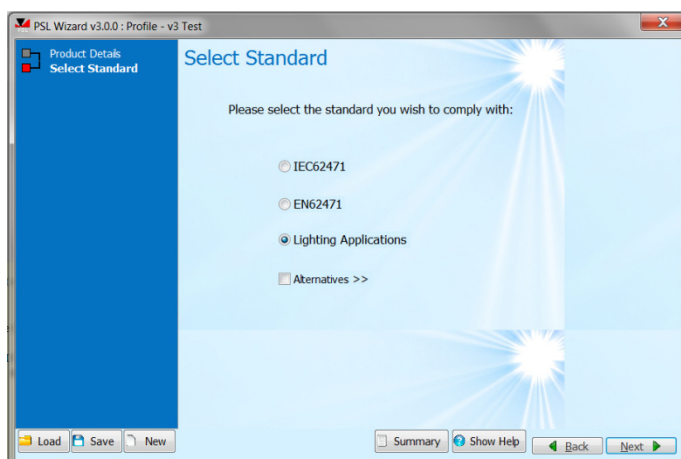
1. Introduction

This document has been written to guide users of the Bentham IDR300-PSL system through the measurement procedure required to evaluate the photobiological safety of lamps.

Issues with the application of IEC 62471, "Photobiological Safety of Lamps and Lamp Systems", in the particular case of sources intended for lighting applications has led to the development of a new approach for these products. Henceforth consideration will be limited (as far as measurement is concerned), depending on source type, to a consideration of actinic UV hazard and blue light hazard through IEC TR 62778.

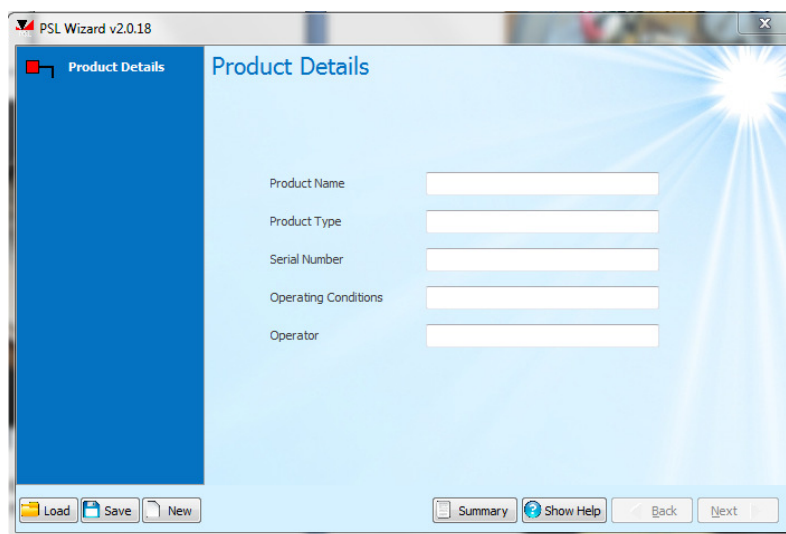
2. PSL Wizard – Lighting Applications

This wizard is designed to facilitate the measurement procedure and results reporting in evaluating the photobiological safety of lamps and lamp systems against IEC62471:2006, EN62471:2008, ANSI RP27, JIS C 7550 and the European Union Artificial Optical Radiation Directive (AORD), 2006/25/EC. From v3, an additional, lighting applications option exists.



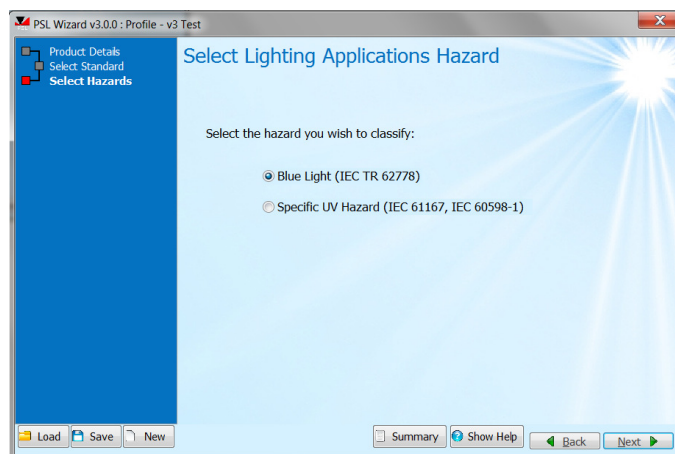
The PSL Wizard is based on profiles, allowing the user to proceed from the input of lamp information, to the reporting of results in stages, with the ability to save and re-load the progress at any point. This permits the user to test a number of samples and progress each wizard analysis in parallel.

To run the PSL Wizard, either "Load" an existing profile or hit "New" to create a new profile. It is recommended to save profiles in the folder where the measurement results of the day are saved. In this manner, PSL Wizard profile, PSL Profiler images, measurement report and measurement results are all located in the same folder.



This guide will provide reference throughout the various stages of use of the PSL Wizard.

Selecting the lighting applications standard route leads to the selection of the consideration of blue light hazard or specific UV hazard.



3. Specific UV Hazard (IEC 61167, IEC 60598-1)

3.1 Applicability

The user should verify the current status of standards.

Specific UV hazard should be considered in the specification of metal halide lamps and in specification of shielding of metal halide lamps (IEC 60598-1 annex P).

In consideration of specific UV hazard, whilst limits are reported with reference to integral quantities (total UV radiant flux, total luminous flux) this measurement can be more simply performed a measurement of spectral irradiance (200-780nm). The measurement distance is not important provide that the spectral distribution measured does not depend on angle or distance. A measurement distance, in consideration of system sensitivity, of 200mm is recommended.

Results for IEC 61167 are separated from that of IEC 65098-1 since the latter restricts the UV measurement range to 200-315nm, whilst the former employs the full 200-400nm range.

3.2 Hardware Setup

- IDR300-PSL with DH-3 photomultiplier and DH-Si silicon detectors
- FOP-UV with D7 cosine corrected input optic
- **(if FOP-UV not connected to monochromator, do not do so until software initialised)**
- USB connected to IDR300
- CL6-H calibration lamp with 605 supply
- CL7 calibration lamp with 706 power supply



Figure 1: D7 Diffuser

3.3 Software Setup

- Initialise Benwin+ in the irradiance configuration

3.4 Calibration Measurement

- Set up CL6 irradiance standard, connect red and black cables and fan
- Ensure current of 605 set to **6.3A**, power on, allowing 5 minutes warm-up period
- Connect the D7 diffuser to the quartz fibre bundle
- Connect the D7 to the CL6
- Go to Scan/ Scan setup, (scan range should be defined 300 to 780nm, if not go to advanced, check use custom wavelength file, and load "CL6_Irradiance_300-780nm ")
- Go to advanced, ensure that data correction is NOT selected
- Define number of scans, suggest three for calibration (one can average more than one scan for better confidence if desired)
- Hit new scan
- Hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to irradiance in name to indicate the nature of measurement)
- Power off CL6 and allow one minute cool-down time prior to moving lamp

To consider the UV:-

- Set up CL7 irradiance standard, connect anode, cathode and heater and power on
- Lamp shall illuminate in one minute
- Connect the D7 to the CL7
- Go to Scan/ Scan setup
- Scan range should be defined 200 to 400nm, if not go to advanced, check use custom wavelength file, and load "CL7_Irradiance_200-400nm".
- Go to advanced, ensure that data correction is NOT selected
- Define number of scans, suggest three for calibration (one can average more than one scan for better confidence if desired)
- Hit new scan
- At the end of the scan, hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to irradiance in name to indicate the nature of measurement)
- Power off CL7

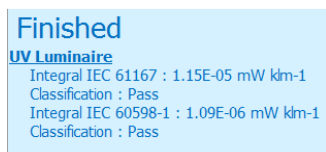
3.5 Applying Calibration

- Go to utilities/ correction calculator
- Spectrum 1 load scan, measurement of CL7
- Spectrum 1 load certificate, certificate file of CL7
- Spectrum 2 load scan, measurement of CL6
- Spectrum 2 load certificate, certificate file of CL6
- Select spectrum two absolute
- Hit show overlap
- Hit save correction file
- Go to Scan/ Data correction, load from file
- Load just-saved correction data
- Follow short- cut to return to scan setup
- Go to advanced, check use custom wavelength file, and load "IEC_TR_62778_Irradiance_300-780nm" custom wavelength file
- The system is ready to perform measurements of spectral irradiance

3.6 Source Measurements

Since the UV hazard is a relative measure, the measurement distance nor alignment should not affect the results, however a measurement distance of 200mm and reasonable alignment is recommended to ensure a good measured signal.

- Set up source under test at 200mm from the D7 diffuser
- Use alignment utility to briefly align for maximum signal at a wavelength emitted by the source (555nm suggested)
- Go to Scan/ Scan setup, load custom wavelength file Specific_UV_Hazard_200-780nm.
- Define number of scans, one should suffice
- Hit new scan
- Hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to irradiance in name to indicate the nature of measurement)
- Load file in PSL Wizard, hit next.
- Measurement results will be presented



Finished
UV Luminaire
Integral IEC 61167 : 1.15E-05 mW km-1
Classification : Pass
Integral IEC 60598-1 : 1.09E-06 mW km-1
Classification : Pass

- Where desired, one export results to a measurement report.

4. IEC TR 62778

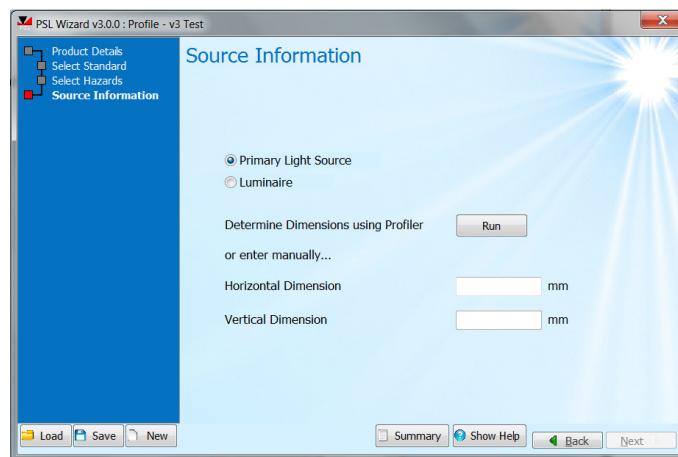
4.1 Overview

IEC/TR 62778 has been written to provide guidance on the assessment of the retinal blue light hazard of all lighting products, from primary light source (lamps and LEDs) to luminaires (finished products), emitting principally in the visible region, 380-780nm, significantly allowing the transfer of data from primary light source to luminaire.

Based upon the assumption that light sources classified as exempt or RG1 for blue light hazard are “safe” (and require no labelling or user information according to IEC/TR 62471-2), IEC/TR 62778 applies a test to determine if, at a distance of 200mm, the source in question exceeds the blue light RG1 emission limit. If an RG2 classification results, the illuminance level, E_{thr} , at which RG1 limit will obtain may be calculated. This may be converted to a threshold distance, d_{thr} , in the case of finished products.

According to IEC 62471, the evaluation of the blue light hazard RG1 requires a measurement of spectral radiance over a FOV of 11mrad. At 200mm, this corresponds to the measurement of a 2.2mm diameter circular area of the source, in which case, it is presumed that the true radiance of the source be measured. Where the RG1 limit is not exceeded, application of the law of conservation of radiance may be used to transfer the classification of a component lamp/ LED to a final product in which this source is used. This procedure does not apply where the source does not fill the 11mrad FOV. In consideration of luminaires, the radiance route can be pursued where the average angular subtense $>11\text{mrad}$ subtends an angle less than 11mrad.

To discriminate between these two paths, selecting blue light hazard in the select lighting applications hazard page leads one to define the types and dimensions of the source.



A primary light source is a lamp or LED; a luminaire is any finished product. The measurement procedure depends on this type.

Given that the decision is based around a 2.2mm circular area, for sources significantly larger than this, recourse to the PSL profiler is not required, one can simply estimate the dimensions of the emitting area of the source.

4.2 Determination of Source Size with a Ruler

It is clearly not possible to determine the 50% emission points of the source using a ruler. In the first approximation, measurement of the light emitting region is recommended.

This case is best demonstrated by an example, here of a linear array, measuring the length and width of the light emitting area, the result of which is 1200x 120mm. These values should be input to the PSL Wizard.



Figure 3: Measurement of linear source size with a ruler

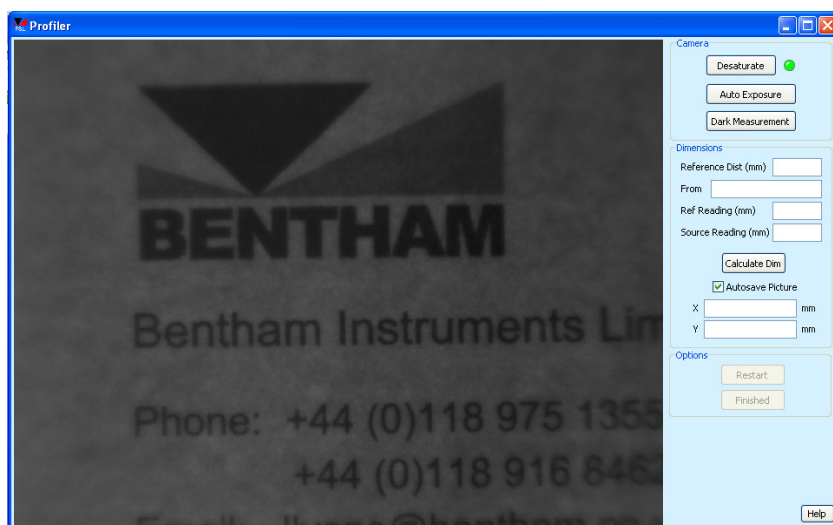
The PSL Wizard will then proceed to determine the average angular subtense of the source. In this case, the GLS measurement distance is 1500mm. Therefore the angular subtense = $(1200/1500 = 0.8) \text{ rad} \times (120/1500 = 0.08) \text{ rad}$. Since $0.8 \text{ rad} > 100 \text{ mrad}$ limit of consideration, this value is set to 100mrad before taking geometrical average to obtain average angular subtense = $(100+80)/2 = 90 \text{ mrad}$.

4.3 Determination of Source Size with the PSL Profiler

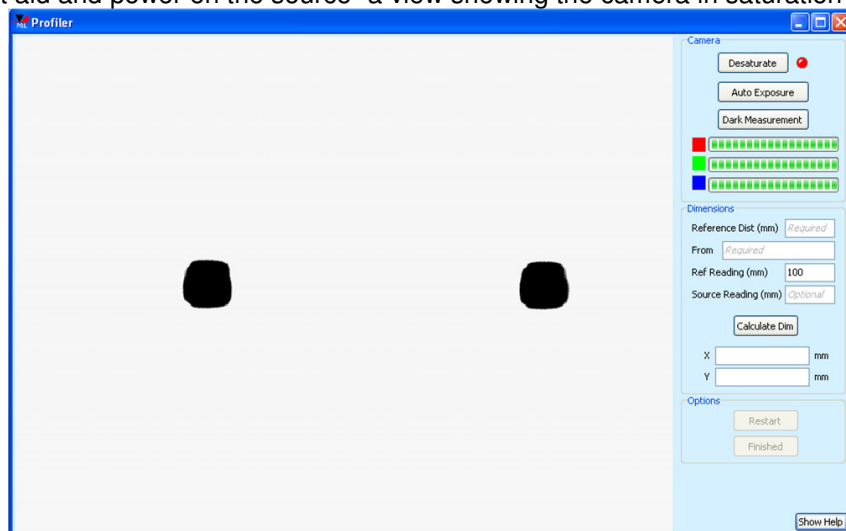
To run the PSL Profiler, ensure the Profiler connected by USB to the computer and hit RUN.

The following notes refer to the setting up of the Profiler at the recommended measurement distance of 200mm. Where the source over-fills the field of view, please find additional notes below.

- Set the Profiler to the 100mm position (mid-way) on rail read-out
- Rotate the filter wheel upwards to engage with the index of the open filter position
- Ensure the iris diaphragm is fully open
- In order to set the Profiler to view 200mm distant, it is recommend to assemble an alignment utility, such as that seen in the following image, and having a target on which to focus, position this 200mm from the front face of the Profiler
- Adjust the position of the translatable lens to get the target into focus, changing height and lateral position as required



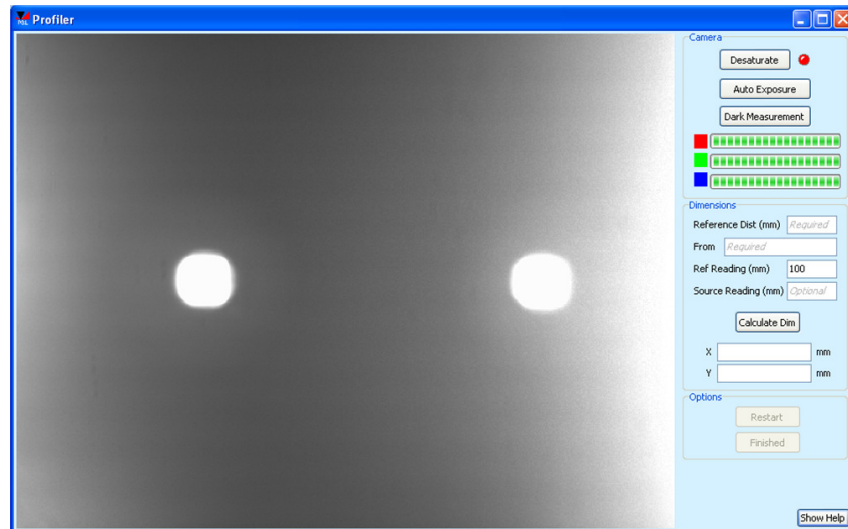
- Position the reference point of the source at the plane of the target. This may be the front window, the front edge of the metalwork etc.
- Remove the alignment aid and power on the source- a view showing the camera in saturation will be presented



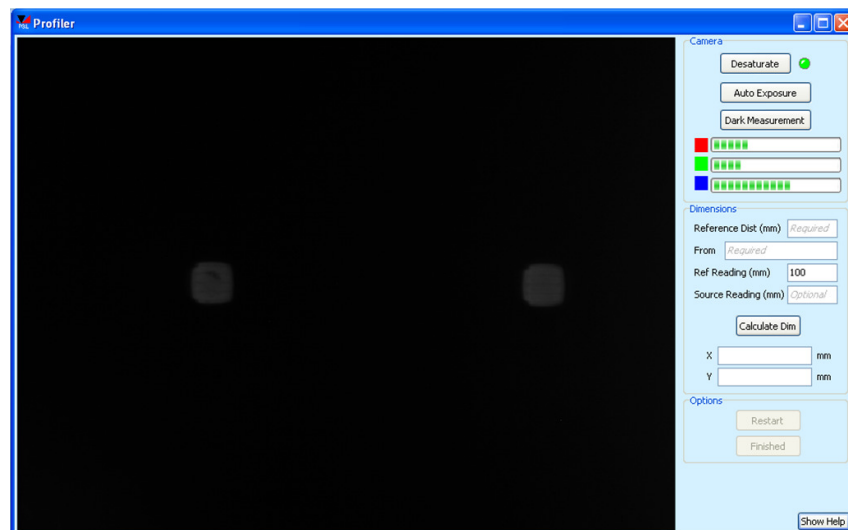
-When saturated, note the red warning light next to the de-saturate button (this turns green when the camera no longer in saturation), and the intensity bars of the RGB sensors.

-As required, rotate the filter wheel downward to insert increasing ND filters and hit the de-saturate button to automatically change the camera settings. Where this procedure fails, the user will be prompted to increase attenuation via ND filters

-In the procedure of de-saturating, it will become clear that the source is not focussed. DO NOT modify the position of the translatable lens, but move the Profiler on the rail toward the source to achieve a clear image



-Continue this process until the camera is not in saturation and a clear image of the source is obtained

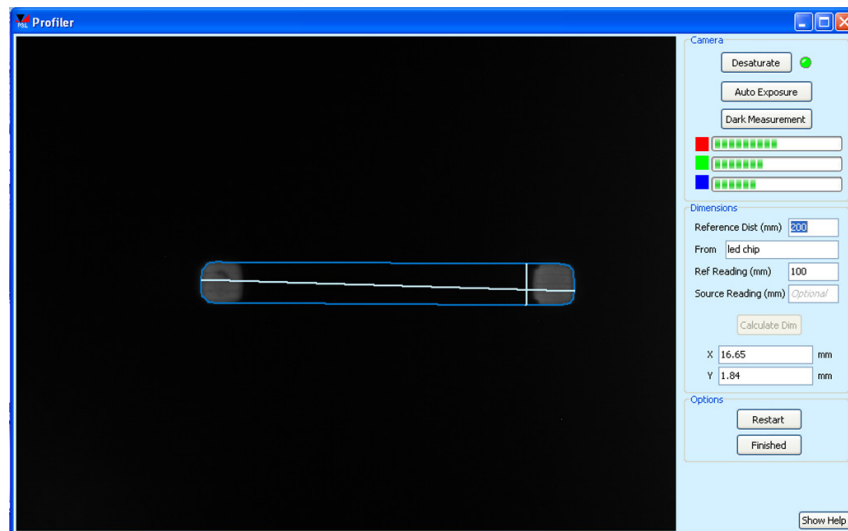


-If during this process it is seen that the source extends beyond the field of view of the profiler, it is necessary to move the source further back, adjusting the position of the translatable lens to keep the source in an approximate focus, to determine the distance at which to perform this analysis. One must then use the alignment aid to focus the camera at the reference point and repeat the above procedure

-When ready, type in the reference distance (the distance at which the system is in focus, here 200mm unless this has been modified where the source overfills the view of the Profiler), a name for the reference point, the reference rail reading is preset to 100mm. Where the Profiler position on the rail had to be modified to get the source in focus, read-off and input the source rail reading, otherwise leave this field blank.

-Hit run, the software will apply the convex hull algorithm and report true source size from which and true source location

-If the camera is still in saturation or under-saturation, the user will be prompted and suitable increase/ reduction of ND filtering will be required.



By hitting finished, the apparent source location will be recorded (and used to prompt for the measurement distance of non-GLS sources, for example “180mm from front window”), and the source dimensions filled in automatically on the PSL Wizard page.

In certain instances, the PSL Profiler may be used merely to determine the source location behind a reference point, but not the source size, where the source size is large. In this case, the computed values for source size reported by the Profiler may be amended.

4.4.1 Sources subtending <11mrad- Blue Light Irradiance Measurement

Here one should consider the blue light small source case through a measurement of spectral irradiance at 200mm. The determined blue light irradiance should then be compared with the RG1 emission limit of 1 W.m-2.

Where the result is below this emission limit, the classification “RG1 unlimited” can be applied to finished products only. In the case of component lamps/ LEDs, the threshold illuminance, E_{thr} , should be reported for inclusion in the product data sheet to allow transfer of this information to the final product.

If the RG1 limit is exceeded, the boundary between RG1 and RG2 should be determined for finished products through determination of the threshold distance, d_{thr} , at which E_{thr} obtains.

5.4.2 Hardware Setup

- IDR300-PSL with DH-3 photomultiplier and DH-Si silicon detectors
- FOP-UV with D7 cosine corrected input optic
- **(if FOP-UV not connected to monochromator, do not do so until software initialised)**
- USB connected to IDR300
- CL6-H calibration lamp with 605 supply

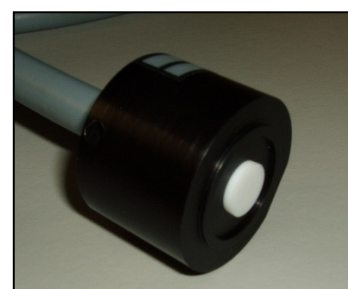


Figure 2: D7 Diffuser

5.4.3 Software Setup

- Initialise Benwin+ in the irradiance configuration

5.4.4 Calibration Measurement

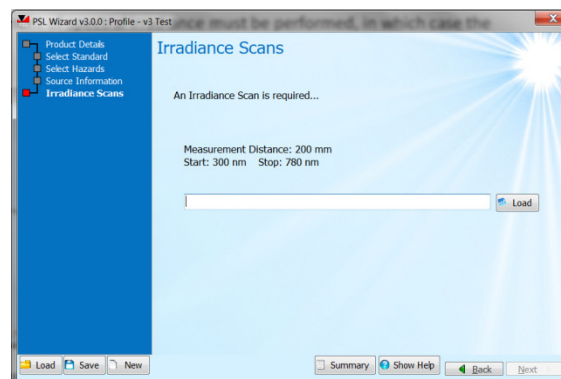
- Set up CL6 irradiance standard, connect red and black cables and fan
- Ensure current of 605 set to **6.3A**, power on, allowing 5 minutes warm-up period
- Connect the D7 diffuser to the quartz fibre bundle
- Connect the D7 to the CL6
- Go to Scan/ Scan setup, (scan range should be defined 300 to 780nm, if not go to advanced, check use custom wavelength file, and load "IEC_TR_62778_Irradiance_300-780nm")
- Go to advanced, ensure that data correction is NOT selected
- Define number of scans, suggest three for calibration (one can average more than one scan for better confidence if desired)
- Hit new scan
- At the end of the measurement, hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to irradiance in name to indicate the nature of measurement)
- Power off CL6 and allow one minute cool-down time prior to moving lamp

5.4.5 Applying Calibration

- Go to scan/ data correction
- Load certificate file for CL6
- For system file, load just- saved system measurement of calibration lamp
- Hit calculate calibration data
- On prompt say OK to the application of data correction forthwith
- Save calibration data for future reference
- Follow short- cut to return to scan setup
- The system is ready to perform measurements of spectral irradiance using the same custom wavelength file as that used for calibration

5.4.6 Source Measurements

- Perform measurements as prompted by the PSL wizard



- Set the source under test at 200mm from the front face of the D7 input optic
- Use the alignment utility, set to a wavelength at which the source emits, (eg 555nm) to find the peak irradiance.
- Return to Scan/ Scan setup
- Define number of scans, one will suffice
- Hit new scan
- At the end of the measurement, hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to irradiance in name to indicate the nature of measurement)
- Load this file into the PSL Wizard, hit next to arrive at the results page
- For all primary light sources, the E_{thr} value will be reported

Finished
Blue Light IEC TR 62778 (Small Source)
Integral : 0.5 W m⁻²
Eth_r : 927.19622 lx

- For small source luminaires, the classification may be RG0, RG1 or Eth_r. If E_{thr} results, then you will be taken to a page in which to evaluate d_{thr} .

5.5.1 Sources >11mrad, Blue Light Radiance Measurement

The measurement of spectral radiance is required in the case of primary light sources under-filling the 11mrad FOV at 200mm and luminaires subtending an angle >11mrad at 200mm. The 11mrad FOV only is used.

In general, the measurement of radiance, compared to that of irradiance, where the diffuser reflects ~99% of incident light, transmits a large amount of incident light to the monochromator. In certain instances, and generally only in the 11mrad FOV (since the aperture in the image plane is larger than that in a 1.7mrad FOV, thereby transmitting more light), the level of light may be too high for exceptionally sensitive PMT.

One can circumvent this problem by either migrating to the less sensitive silicon detector (a very significant change) or modifying the system bandwidth by closing the entrance and exit slits, thereby transmitting less light through the system to the detector.

In the TEL309 utility, a high radiance mode allows automatic migration from the PMT to Silicon detector, in the vicinity of 400nm, for the 11mrad FOV only. The decision of precisely at which wavelength the changeover is made varies system to system as the throughput of each system is slightly different, but is generally in the range 400-420nm. Different custom wavelength files are employed for the 11mrad and 1.7mrad FOV to avoid where possible system overload, but to ensure the system is sensitive enough to perform a satisfactory measurement.

The custom wavelength file for the 11mrad FOV measurement, "IEC_TR_62778_Radiance_11mrad", steps in 2nm up to the point of changeover to the silicon detector then 5nm thereafter. The custom wavelength file for the 1.7mrad measurement, "radiance1_7mrad.dat" steps in 2nm to 480nm, then 5nm thereafter. This has been selected to ensure narrow bandwidth in the vicinity of the white PC-LED blue LED peak where the PMT is particularly sensitive.

The decision of high radiance mode depends on the sample under test. In general fluorescent lamps and sources with diffusers should not need the high radiance mode, and indeed these sources are quite comfortable to view showing that the luminance will be low relative for example to a high power LED chip which is not comfortable to view and would require the high radiance mode. Where the signal is too high, an "ADC overload" message will be returned. To move to high radiance mode in this case would require re-calibration of the system.

Once calibrated the mode should not be changed.

5.5.2 Hardware Setup

- IDR300-PSL with DH-3 photomultiplier and DH-Si silicon detectors
- TEL309 with quartz fibre bundle
- **(if FOP-UV not connected to monochromator, do not do so until software initialised)**
- TEL309 powered on
- USB connected to IDR300 and TEL309
- SRS12 calibration lamp with 605 supply



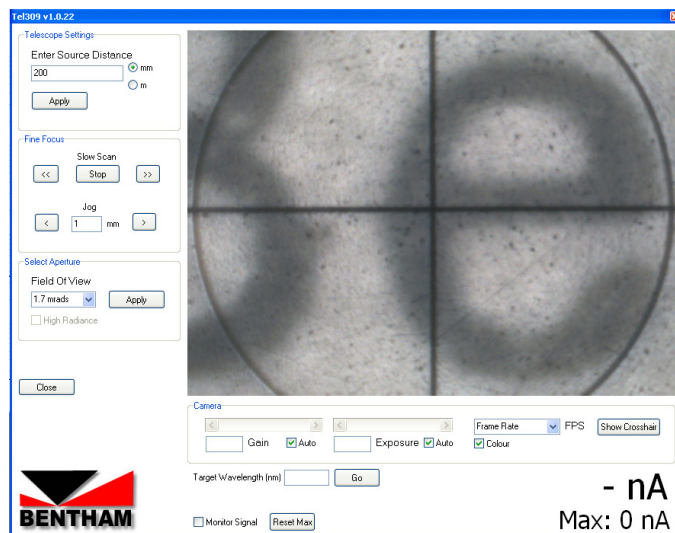
Figure 3: TEL309

5.5.3 Software Setup

- Initialise Benwin+ in the radiance configuration

5.5.4 Calibration Measurement

- Position SRS12 in front of TEL309, the final location of the SRS12 will be performed using the camera of the TEL309
- Set up SRS12 radiance standard, connect red and black cables
- Ensure current of 605 set to **8.5A**, power on, allowing 5 minutes warm-up period
- Go to utilities/ TEL309
- Input measurement distance (here 200mm), hit apply and ensure close-up lens in place upon prompt
- Cross-hair view will be seen
- Set the SRS12 front plane to the imaging plane of the TEL309 by placing a business card or other alignment aid at the plane and adjusting the position of the SRS12 to get the text of the business card in focus



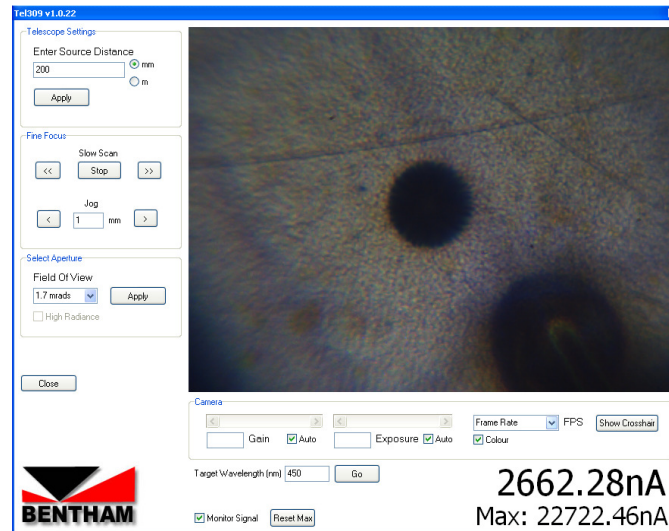
- Ensure area of SRS12 approximately central
- In the TEL309 window, select 11mrad
- At 200mm the view of the camera of the TEL309 is ~11mrad, so not much of the source will be seen (where there is black is where the monochromator measures)
- Select high radiance mode where required
- Go to Scan/ Scan setup, go to advanced
- Ensure that the "IEC_TR_62778_Radiance_11mrad" custom wavelength file is selected
- Ensure that data correction is NOT selected
- Define number of scans, suggest three for calibration (one can average more than one scan for better confidence if desired)
- Hit new scan
- At the end of the measurement, hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to radiance and the field of view (11mrad here) in name to indicate the nature of measurement)
- Repeat the above procedure with high radiance mode set in opposite state where required.

8.4 Applying Calibration

- Go to scan/ data correction
- There should be no need to load certificate file (if not selected, load SRS12 certificate file)
- Load system file of measurement of calibration lamp with 11mrad FOV
- Hit calculate calibration data
- Save calibration data for future reference
- Repeat where applicable for the second high radiance mode state
- The system is ready to perform measurements of spectral radiance with 11mrad FOV

8.5 Source Measurements

- Go to utilities/ TEL309
- In the TEL309 window, for the purposes of alignment, select 1.7mrad
- At the bottom of the page, input a target wavelength at which to perform alignment and hit monitor signal. The current and maximum values will be reported



1.7mrad aperture selected

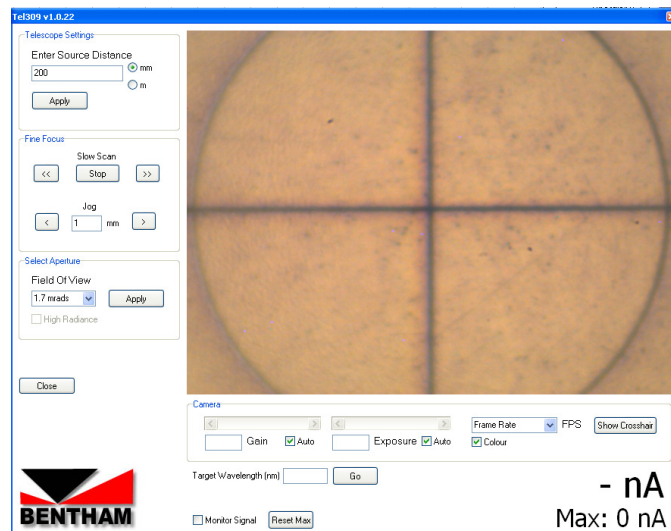


Signal monitor

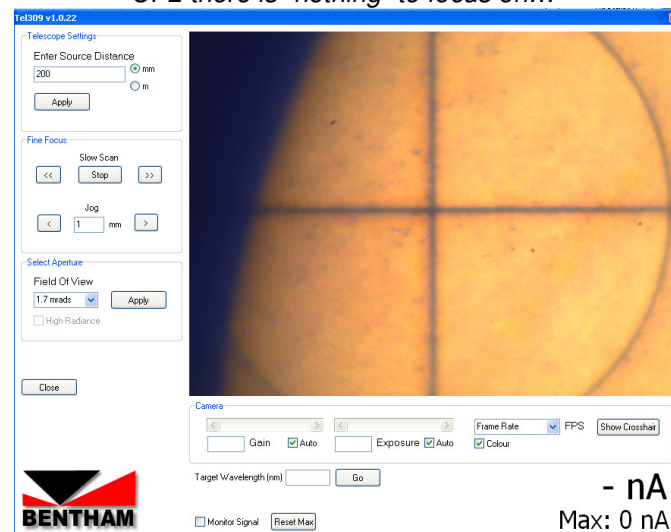
- Position source to get it into **focus** on the TEL309 camera- what is sought is what the eye would view, LED chip, diffuser, etc. In many instances it is not clear what is being looked at!
- Where the source incorporates a diffuser with nothing to focus on, it may be useful to place a business card or alignment aid on the emission surface to aid in positioning the source



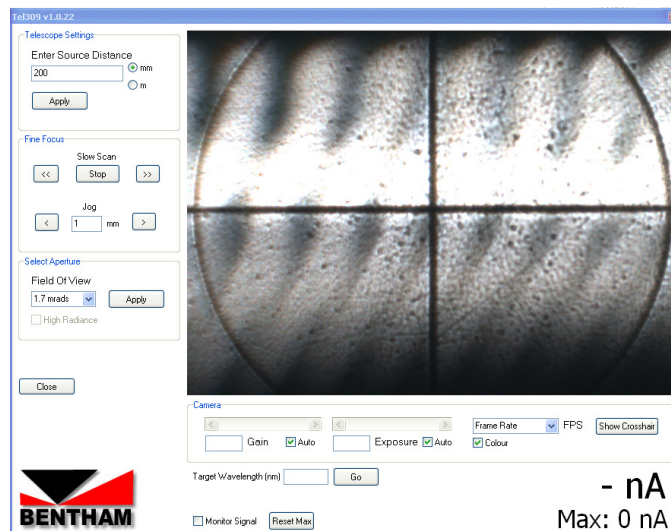
White PC-LED chip- the phosphor acts as a diffuser so it is not clear what is being viewed other than the grid of electrical connections and the wire bond



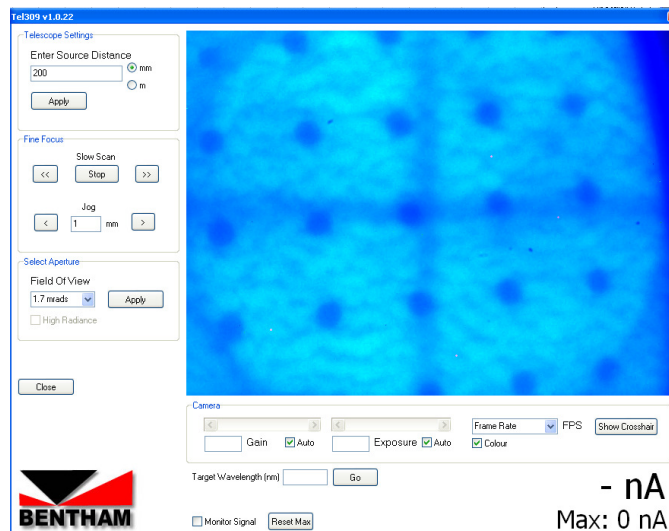
CFL-there is "nothing" to focus on...



...but it can be useful to look at the side of the source to get the edge into focus

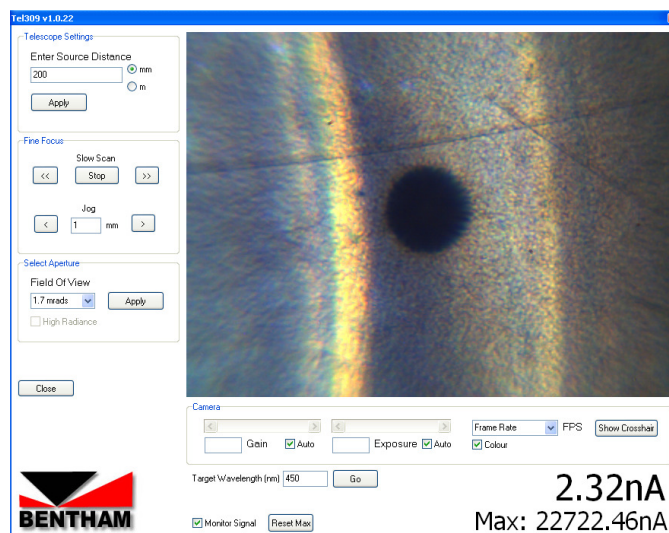


Incandescent lamp filament



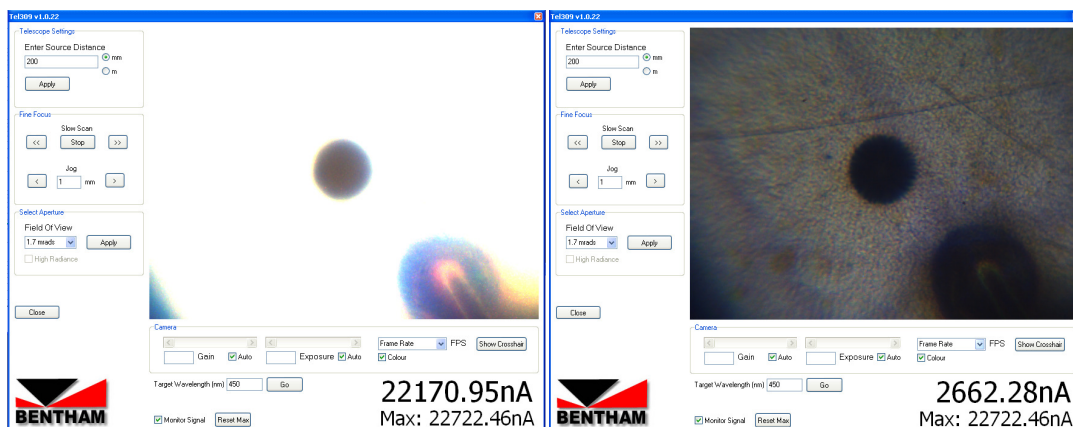
Contrary to the case of PC-LEDs, coloured LEDs do not have a diffusing phosphor layer so one can see the chip very clearly

- The key to this process is moving large amounts to determine what is being viewed and having in mind that the full view of the CMOS camera at 200mm is ~2.2mm at the source



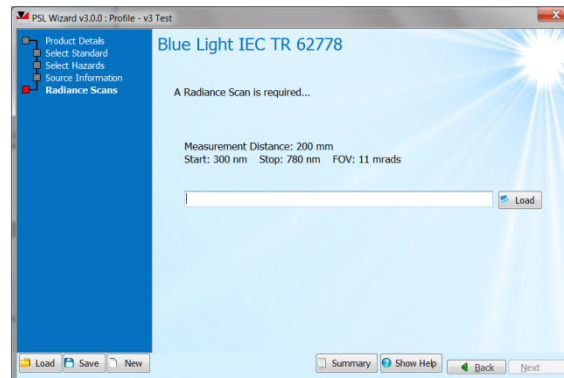
Visual cues, such as this reflector to the side of an LED can help guide the user in the alignment of the source (circular reflector, one should move to the left of this image to "find" the LED chip)

- Optimise source position for maximum signal, and try to centre source on screen so that it will be central to the 11mrad FOV when selected
- Where the signal level saturates the CMOS camera in the TEL309, the 7mm aperture can be placed in the TEL309 lens to reduce signal (**ensure this is removed prior to measurement otherwise an incorrect measurement will result**)



- Finally select 11mrad FOV

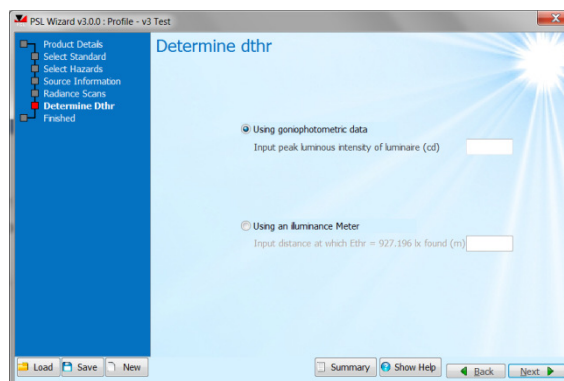
- If the measurement setup is very stable, a slight adjustment for maximum signal may be made, but since there is no visual feedback, no more than slight movement should be made
- Remove the 7mm aperture where this was used to reduce the signal on the camera
- Close TEL309 and perform new scan
- Save result, giving appropriate name (it is recommended to include reference to radiance and the field of view (11mrad here) in name to indicate the nature of measurement)
- Close measurement in Benwin+
- Pass result to PSL-Wizard



- Hit next. If the blue light radiance is below the RG1 limit, will be returned the result RG0 or RG1

Finished
Blue Light IEC TR 62778
 Integral : 1.5E+03 W m-2 sr-1
 Classification : RG1

- Where the RG1 radiance limit is exceeded, and the source type luminaire, the user will be prompted to perform a measurement or calculation to determine dthr. This can be measured by directly finding Ethr using the virtual luxmeter of the IDR300-PSL in the direction of maximum intensity, and computed where existing goniophotometric data is available, by inputting the maximum luminous intensity (cd). Please note that where goniophotometric data is reported in cd/klm, this value should be multiplied by the bare lamp flux (or luminaire total luminous flux in case of SSL) prior to proceeding.



- The computed value of dthr is included in the report.

Finished
Blue Light IEC TR 62778
 Integral : 2E+04 W m-2 sr-1
 Classification : RG2
 Ethr : 927.19623 lx
 dthr : 3.28 m

In all cases, one can export the results to a report.

