IEC62471 Evaluation with the Bentham IDR300-PSL

Measurement Procedure

Version 5- April 2016

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1. Introduction

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

This document refers to IEC62471:2006/ EN62471:2008, and the measurement procedure stated should be considered an interpretation thereof. The reader should verify the existence of updated versions of this standard which may apply.

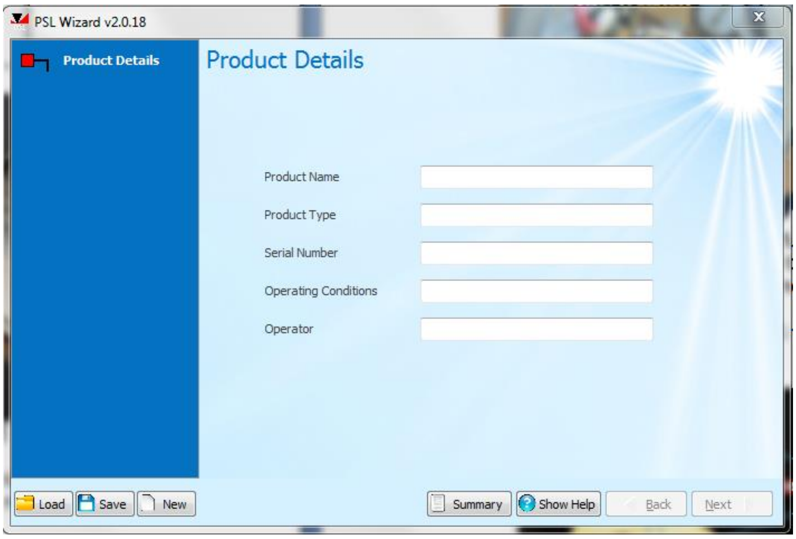
In the appendix is given installation information to assist with the initial setup and the setting up of the various configurations.

2. PSL Wizard

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.

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.

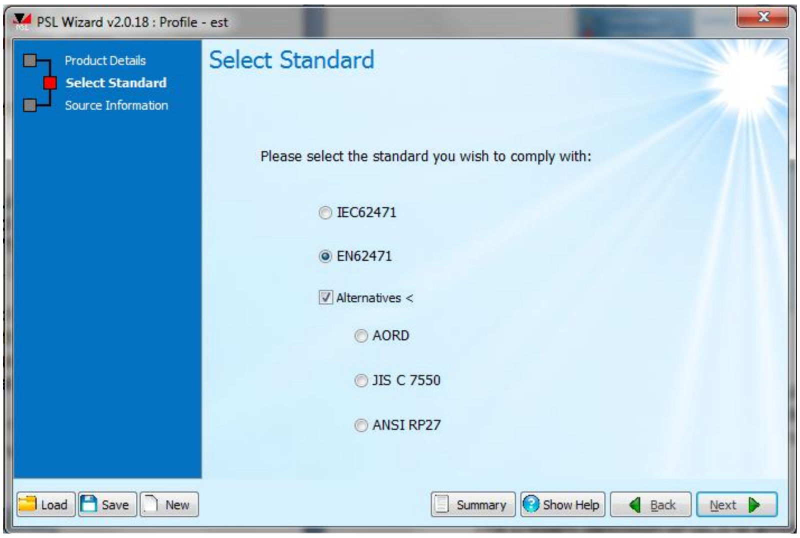


This guide will provide reference throughout the various stages of use of the PSL Wizard.

3. Applicable Standard

The PSL Wizard can provide an evaluation against one standard only.

Whilst IEC62471:2006 and ANSI RP27 are effectively the same (IEC62471 is an adoption of CIE S009 which is based on ANSI RP27), the limits of EN62471:2008 and the AORD differ slightly from those of IEC62471:2006, the spectral range of JIS C 7550 is reduced to 2500nm as opposed to 3000nm.



4. Measurement Distance and Angular Subtense

The distance at which a source should be evaluated depends upon its intended application to permit consideration in a likely exposure scenario, taken broadly as general lighting service (GLS) and all other applications (non-GLS).

The angular subtense of the source indicates the area of the retina exposed and is required in consideration of retinal hazards.

4.1 GLS

The present definition of GLS is ambiguous, but relates to finished products intended for illuminating spaces which emit “white” light. This “white” part of the definition is missing from the standard. To this the author adds some notion of “wide area illumination” to distinguish from directional sources- the scope of GLS should not, in the author’s opinion, include for example torches or directional sources.

GLS sources are evaluated, not necessarily measured, at a distance at which they produce an Illuminance of 500 lux, which distance may be less than a metre for household luminaires, but many metres for street lighting for example. The measurement distance should not be less than 200mm.
The GLS 500lx distance may be measured with respect to a chosen (reported) reference point on the source.

Whilst irradiance measurements may be performed at a convenient distance and scaled to 500 lux, physiological radiance, dependant on the source subtense with respect to the applicable FOV, should be performed at the correct distance. A particular consideration is the testing of discrete sources which are intended for integration in a luminaire, but which are presented as a non-finished product. In such cases, the measurement should be performed at 200mm; since the source is not a finished GLS source, for example, measurement at 500lx would be inappropriate.

4.2 Non-GLS

The non-GLS category encompasses all other sources, including include specialist lamps, UV lamps, IR lamps and coloured and infra-red LEDs.

Non-GLS sources should be measured at a distance of 200mm from the (apparent) source, which distance represents the near point of the human eye: closer than 200mm, the retinal image is out of focus, resulting in lower retinal irradiance.

Here, the concept of apparent source is important. Where a lens is used to collimate the output of an LED, a magnified virtual image is produced behind the chip. It is with respect to this apparent source that the 200mm measurement distance should be taken since it is this which the eye images.

For a bare source, the measurement distance can be taken from the front surface that the eye would image; for example for a source with a clear window, the eye would image the source behind the window, whereas for a source with a diffuser, the eye would image the diffuser.

Where access is restricted to the apparent source such that exposure at 200mm cannot be achieved, the evaluation should be performed at this minimum accessible distance (>200mm).

4.3 Worst Case Exposure Scenario
Whilst the measurement at 200mm may represent a worst-case exposure condition for the retina, this is not the case for the skin and front surfaces of eye where the exposure distance may be closer.

This latter eventuality has not yet been taken account of in this standard for which the primary concern is acute retinal damage. This consideration may be important with regards implementation of the EU artificial optical radiation directive (AORD), 2006/25/EC concerned with worker exposure to non-laser sources of optical radiation.

4.4 Source Angular Subtense
The eye images the source viewed directly onto the retina, for momentary exposure, the subtense of the retinal image, α_{eff}, is the same as that of the source at the evaluation distance. Knowledge of the size of the retinal image is to a certain extent required for evaluation of the retinal hazards.

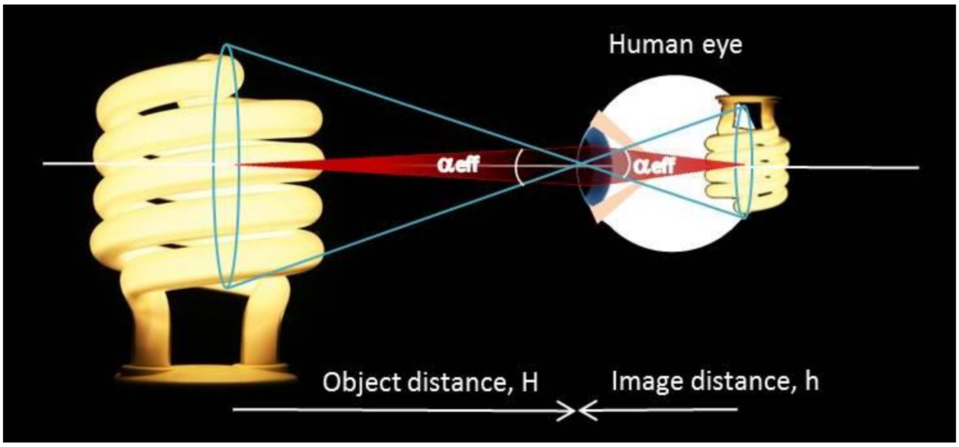


Figure 1: Source and retinal image angular subtense

The range of angles considered by standard is limited to 1.7- 100mrad since the retinal image produced in viewing a source subtending less than 1.7mrad will be no less than 1.7mrad due to aberrations of the eye, and limits are taken as independent of the angular subtense of the retinal images above 100mrad.
The report angular subtense should be the geometric average of orthogonal subtenses, limited prior to averaging to the range 1.47 to 100mrad, ie. if α <1.7mrad, set to 1.7mrad; if α >100mrad, set to 100mrad before averaging.

In the case of the blue light retinal hazard, where the source subtends an angle less than 11mrad, a simplified irradiance based blue light small source analysis may be applied.

In the case of consideration of the retinal thermal hazard, heat incident on the retina can evacuate the area by axial and radial thermal dissipation. The larger the irradiated area, the less heat can dissipate due to lower radial dissipation, leading to damage. It follows that the retinal thermal hazard exposure limits are inversely proportional to angular subtense.

4.5 Determination of (Apparent) Source Size and Location

A distinction should be made from the outset between a “real” physical source (such as an LED chip) and apparent source resulting from magnification of the source by a lens used to collimate the source emission (such as the virtual image of the chip created by a lens), as depicted in the following analogous example of the use of a magnifying glass.

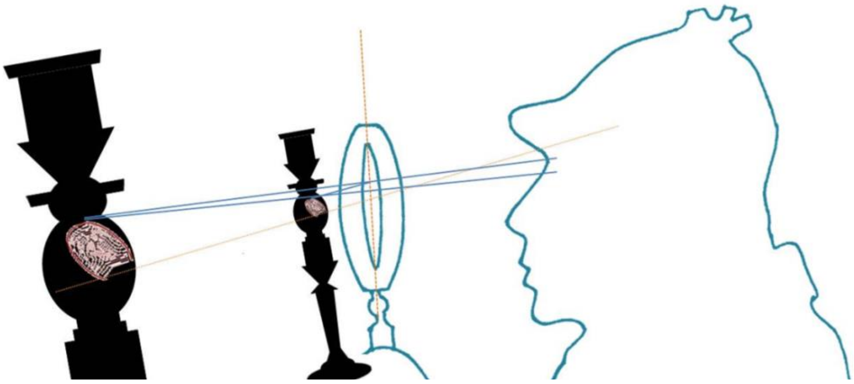


Figure 2: Virtual image as apparent source

The virtual image is erect, magnified and located behind the physical source. It is this virtual image or apparent source that is viewed by the eye, and therefore in the case of non-GLS sources, from the location of this apparent source that the 200mm measurement distance should be taken. The distance from a reference point on the source to the location of the apparent source may be determined by the PSL Profiler.

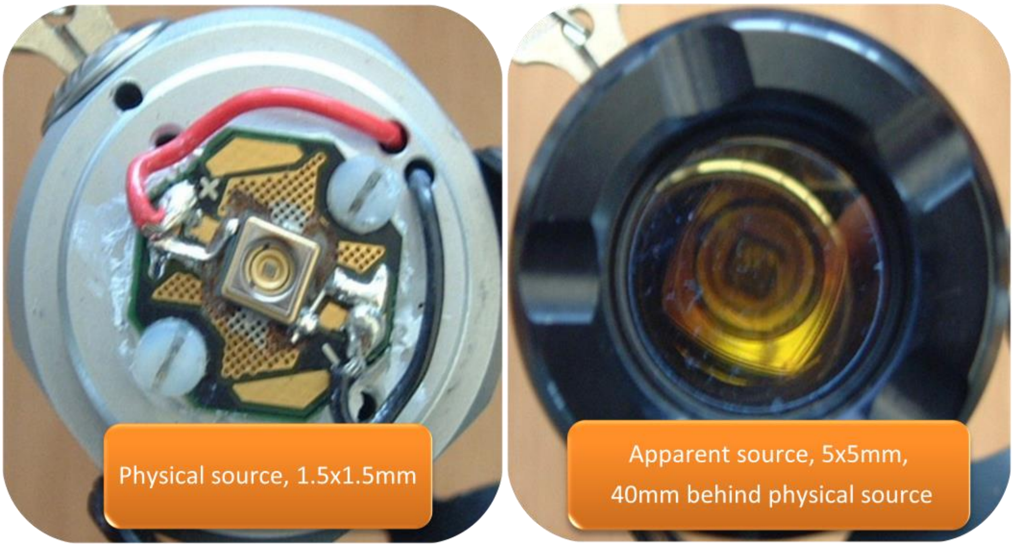


Figure 3: Examples of physical and apparent sources

Now, in terms of source size, there is limited guidance in IEC62471, but it is stated that this should be based on the 50% emission points of the source.

As noted in section 4.7, whilst the (apparent) source size may be determined using the PSL Profiler, the latter has a limited view which makes measurement of large sources potentially problematic. The use of a ruler to simply measure the emission area of the source is an acceptable way to address this question. Care should, however, be taken when using this technique with filament lamps having a diffuse coating on the envelope and other sources fitted with a diffuser since the emission area may not be uniform.

Care should also be taken in the case of sources incorporating reflectors- it may be found that the 50% emission areas be defined by the source only, or this may include the reflector, and the determination may be very sensitive to the angular orientation of the source. Determination of measurement distance in this case is rather problematic since the source is spread over a finite depth as opposed to one emission plane.

Difficulty may also be encountered in the determination of the size of an array of LEDs with lensed packages- since the packages are rarely found to be pointing in precisely the same direction, the PSL Profiler will not see the direction of maximum intensity from each, which will have an impact on the determined source size.

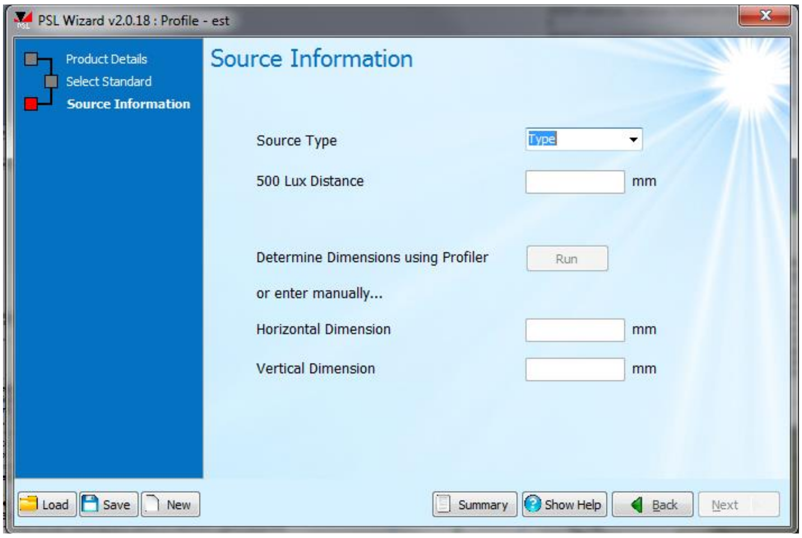
4.6 PSL Wizard

The next page of the PSL wizard requests for information about the measurement conditions of the source.

If GLS, the 500 lux distance should be input (see next section). If non-GLS or worst case, the measurement distance is set to 200mm.

One has then the choice of inputting manually the horizontal and vertical dimensions of the source, or to use the PSL Profiler to determine source size and (apparent) source location.

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



The decision to simply measure the source using a ruler, or using the profiler is largely decided by the size of the source. The PSL Profiler has a limited view of ~120mrad (in order to maintain sufficient CMOS camera resolution for the smallest, 1.7mrad, sources). Practically, the distance at which the source must be placed for the profiler to capture the entire source is 8.3 times the maximum dimension of the source, which can indeed result in impractically long measurement distances.

4.7 Determination of 500 lux distance

The IDR300-PSL DH400-VL lux meter should be connected to the luxmeter amplifier port to the base of the IDR300 and the detector head mounted to view the source.

The meter utility software should be run from BenWin+/ utilities/ meter utility. This requires that one of the BenWin+ configurations be initialised.

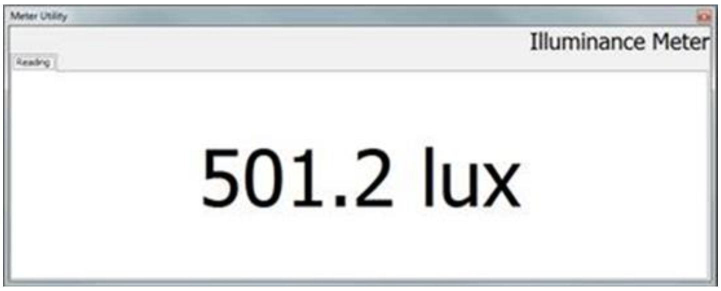


Figure 4: Meter Utility virtual luxmeter

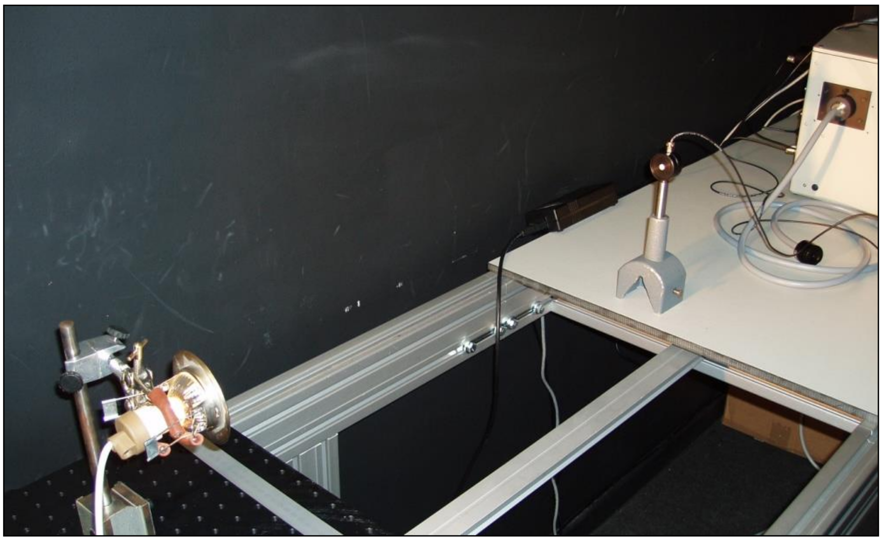


Figure 3: Determination of 500lx distance

Align the source horizontally and vertically with respect to the lux meter, then adjust the distance to obtain approximately 500 lux on the lux meter, ensuring that the direction of maximum output be measured.

Note the distance from the front face of the photometric detector (front of white PTFE surface) to a suitable reference point on the source under test.

4.8 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.

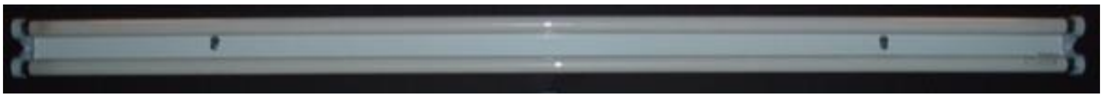


Figure 3: Measurement of linear source size with a ruler

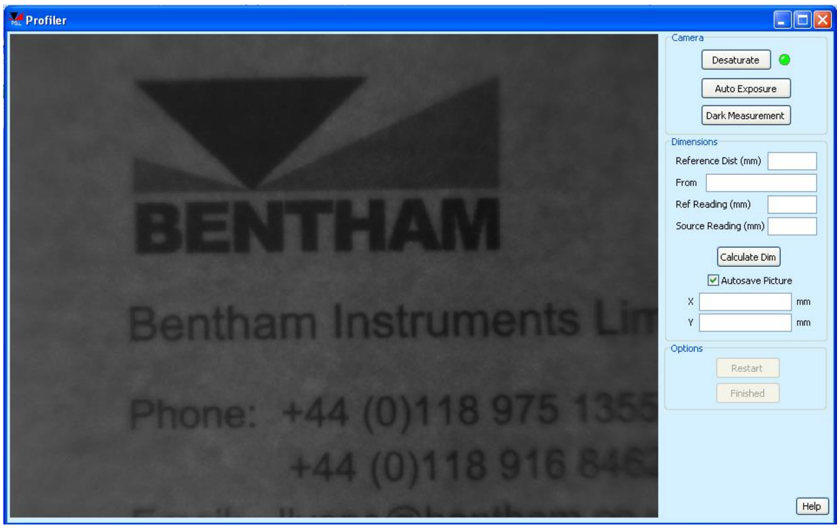
The PSL Wizard will then proceed to determine the average angular subtense of the source. In this case, the GLS measurement distance is 1500mm. Therefore the angular subtense = (1200/1500= 0.8) rad x (120/1500=0.08) rad. Since 0.8 rad > 100mrad limit of consideration, this value is set to 100mrad before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

4.9 PSL Profiler

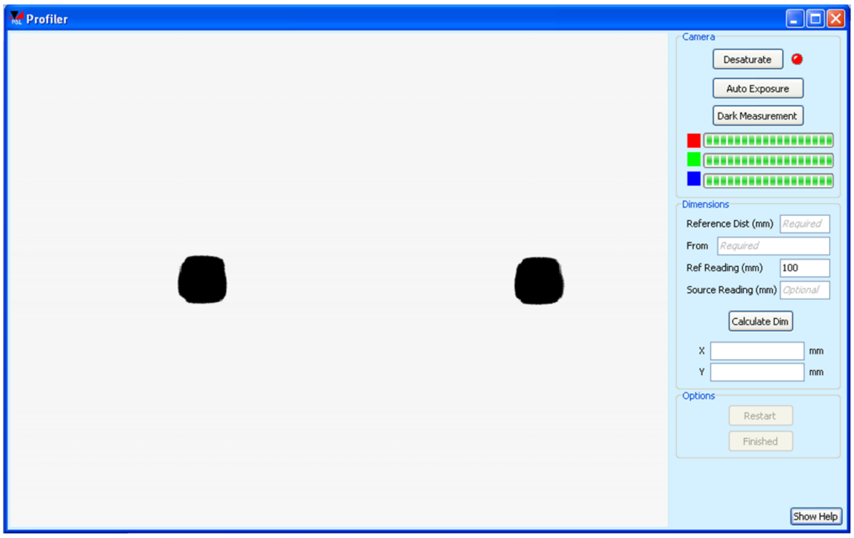
To run the PSL Profiler, ensure the Profiler connected by USB to the computer and hit RUN.

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

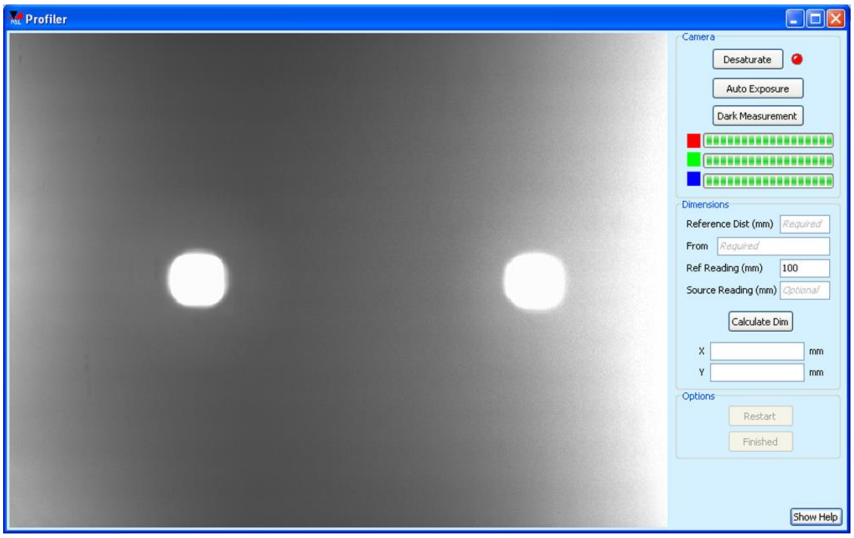
- 

- 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

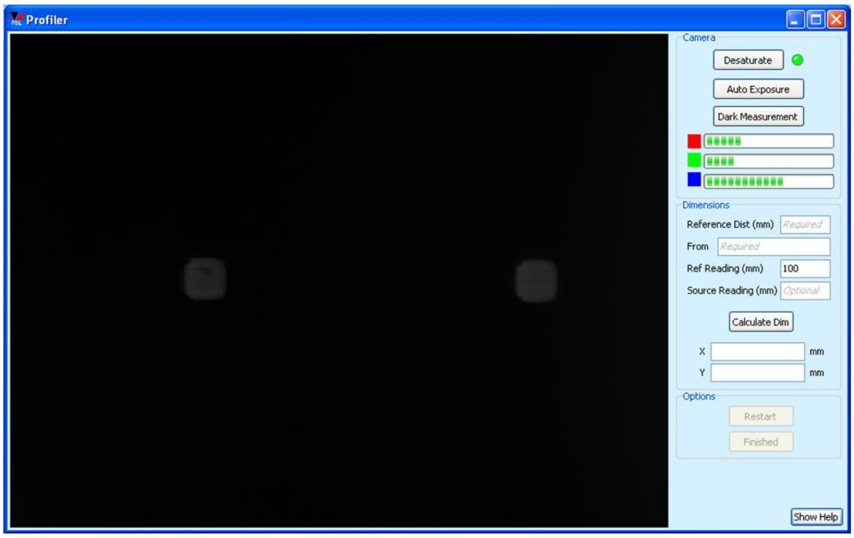


- When saturated, note the red warning light next to the de-saturate button (this turns green when the camera no longer in saturation), and the intensity bars of the RGB sensors.

- 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

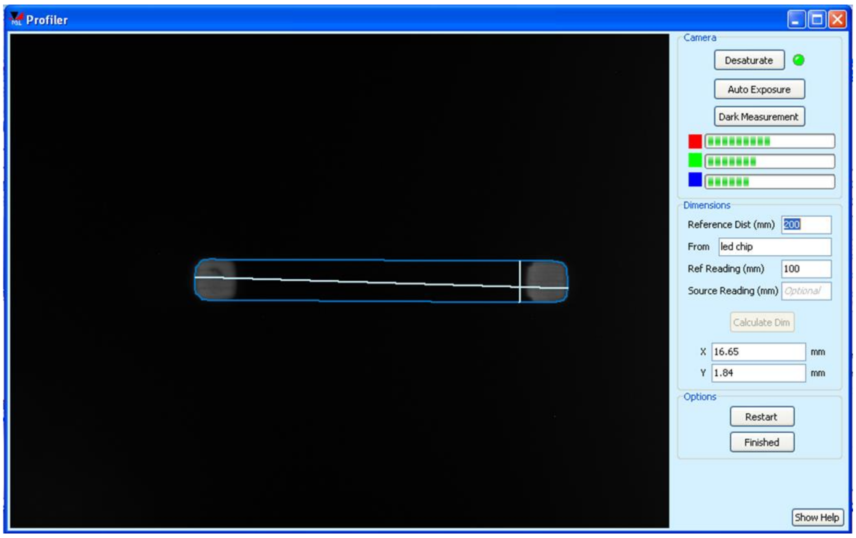


- Continue this process until the camera is not in saturation and a clear image of the source is obtained



- 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.

5. Spectral Check Measurement

The spectral check measurement is an optional measurement that uses the full range of the IDR300-PSL DC configuration to determine via a high throughput measurement where there is light emission through a relative spectral measurement. This may be useful to determine the requirement of performing or note UV or IR measurements. The judgement is left with the user since to automate this decision is not easy!

Since the quartz fibre bundle has an OH^- absorption feature at 1380nm, this cannot be calibrated out and will be seen as an artefact in measurement results. This may be largely ignored for the purposes of these measurements.

5.1 Hardware Setup

- IDR300-PSL with PMT, Si, InGaAs
- FOP-UV with spectral check input optic **(if FOP-UV not connected to monochromator, do not do so until software initialised)**
- CL6-H calibration lamp with 610 supply

5.2 Software Setup

- Initialise BenWin+ in the spectral check configuration

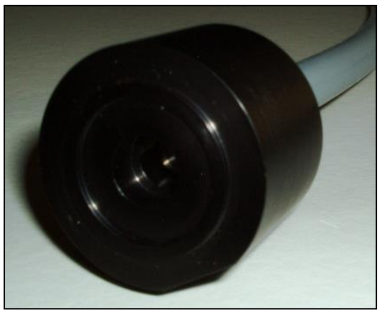


Figure 4: Spectral check optic

5.3 Calibration Measurement

- Set up CL6 irradiance standard, connect red and black cables and fan
- Ensure current of 610 set to **6.3A,** power on, allowing 5 minutes warm-up period
- Connect the spectral check input optic to the quartz fibre bundle
- Connect the spectral check input optic to CL6
- Go to Scan/ Scan setup (scan range should be defined 200 to 1700nm, if not go to advanced, check use custom wavelength file and load “spectral check”)
- Go to >>advanced, ensure that data correction is NOT selected
- Define number of scans, suggest three for calibration to have confidence in stability of system and stabilisation of lamp
- Hit new scan
- At the end of the scan, go to analysis/ spectral average, hit ok to take average of all scans

- Go to analysis/ delete spectra, select original measurement to delete, leaving average
- Hit save as or go to file/ save as, giving appropriate name (it is recommended to include reference to spectral check in name to indicate the nature of measurement)
- Power off CL6 and allow one minute cool-down time prior to moving lamp

5.4 Applying Calibration

- Go to scan/ data correction
- There should be no need to load certificate file (if not selected, load **extended** version of CL6 certificate file)
- 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 relative spectral output

5.5 Source Measurements

- Position source at 200mm from input optic (measurement distance not important in this relative measurement, but closer than 200mm could potentially damage fibre bundle if source emits a lot of heat)

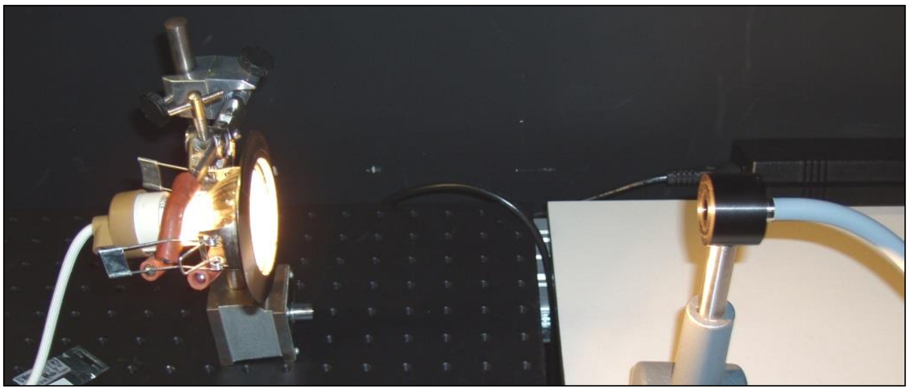
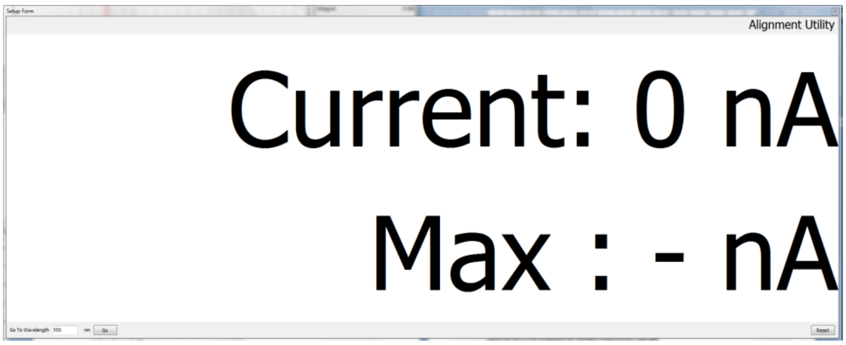


Figure 5: Spectral check measurement

- Use alignment utility to quickly optimise alignment (alignment not critical here, but better measurement result will be obtained)
- Go to meter/ alignment utility



- In bottom left go to wavelength field input suitable wavelength for source (for example 555nm the peak of the eye response for white light.
- If not sure what wavelength to employ, make an approximate alignment, perform a quick scan, inspect the result to see where light is emitted and select a wavelength in a region of strong emission, not necessarily the peak)
- The measured photocurrent shall be presented
- Adjust source position to obtain maximum value
- The maximum value is reported to help in alignment, this can be reset using the bottom right button

- Close when finished.
- Hit new scan and save file at end of measurement

5.6 Interpretation of Results

The resulting spectrum of this high throughput measurement shows a sensitivity much higher than the irradiance measurement and therefore provides the user with information of where light is emitted and where it is necessary to perform a measurement.

Consider for example the following measurements of a white LED and a halogen lamp. I can be seen that for both sources in the UV is seen merely noise, whilst in the infra red there is significant output in the case of the halogen lamp.

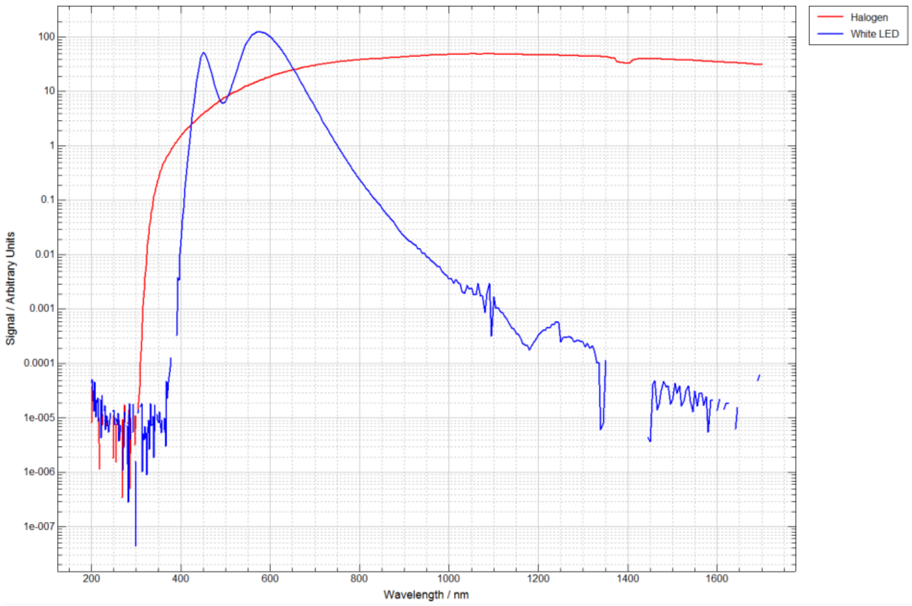


Figure 6: Spectral check result of LED and halogen lamp- note no UV nor IR output from LED

Comparing these spectra with the noise level of the lower throughput irradiance measurement 200-1100nm one can determine at which portions of the spectrum signal will be measured.

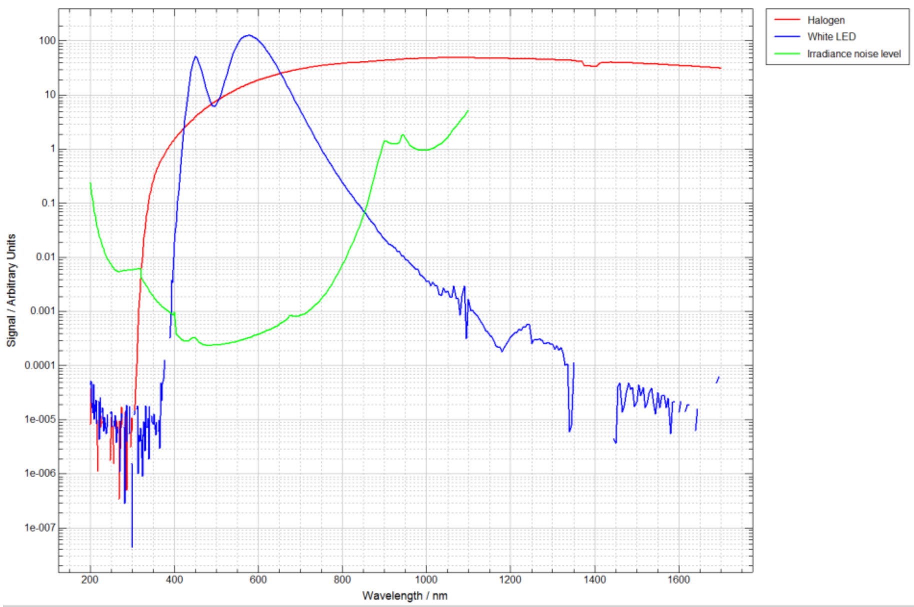


Figure 7: An attempt at seeking a more objective meaning to the spectral check result

It is recommended to base any decisions on spectral regions relative to clearly distinguishable noise levels where for example here the smooth LED output degenerates to noise at both shorter and longer wavelength. If it cannot be measured by the high sensitivity spectral check measurement, it will be below the noise floor of any irradiance measurement.

6. Selection of Hazards to Consider

The next page of the PSL Wizard allows selection of the hazards to consider.

- The actinic UV, near UV and blue light exempt risk groups may be evaluated through a measurement of irradiance 200-700nm, which should be extended to 1100nm should the IR eye and thermal skin hazards be considered
- The blue RG1, RG2 and retinal thermal hazard may be evaluated through a measurement of radiance 380-1400nm
- Evaluation of the IR eye and thermal skin hazards requires an infra-red measurement 1000-3000nm

For GLS sources, it is recommended not to select retinal thermal since this requires calibration and measurement of the retinal thermal hazard at the GLS distance. For each GLS lamp, a new calibration and measurement would be required which will constitute a significant amount of work. Now it can be shown that at 500 lux only very high colour temperature LED sources will be above the blue light exempt risk group, for which it can be shown by calculation that the retinal thermal hazard will be exempt also.

This restriction need not be in place for non-GLS sources since one calibration at 200mm will serve all measurements.

7. Irradiance Measurement

The measurement of spectral irradiance permits the direct determination of the UV, blue light exempt and blue light small source hazards, and is used in the calculation of the IR hazards. Whilst the UV and IR eye hazards need only be performed over a 1.4 radians view, the blue light exempt risk group need only be performed over a 100mrad FOV. Apertures may be required to limit the emission of the source. In the case of the consideration of blue light hazard in a 100mrad FOV and retinal thermal weak visual stimulus hazard in a 35mrad FOV, both for non-GLS sources, the DIFF_D7_FOVL is provided.

The D7 diffuser can only be used over the range 200-1100nm, beyond 1100nm, the cosine response of this optic breaks down. In general, for the avoidance of confusion, it is recommended to perform source measurements either 200-1100nm or 300-1100nm even where data up to 1100nm may not be required. Care should otherwise be exercised to ensure that the measurement bandwidth during calibration is exactly replicated in source measurement.

7.1 Hardware Setup

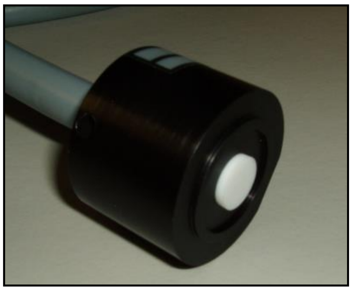


Figure 8: D7 Diffuser

- IDR300-PSL with PMT, Si, InGaAs
- 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 610 supply
- Where measurements in the UV are required, CL7 calibration lamp with 705 power supply
- DIFF_D7_FOVL where required

7.2 Software Setup

- Initialise BenWin+ in the irradiance configuration

7.3 Calibration Measurement

- Set up CL6 irradiance standard, connect red and black cables and fan
- Ensure current of 610 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 1100nm, if not go to advanced, check use custom wavelength file, and load CL6 Irradiance calibration)
- 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
- If calibrating only in the 300-1100nm region, at the end of the scan, go to analysis/ spectral average, hit ok to take average of all scans (using the correction calculator to combine the UV and VIS-IR calibrations performs the averaging process)
- Go to analysis/ delete spectra, select original measurement to delete, leaving average
- 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

Where a measurement is also required in 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 calibration
- 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

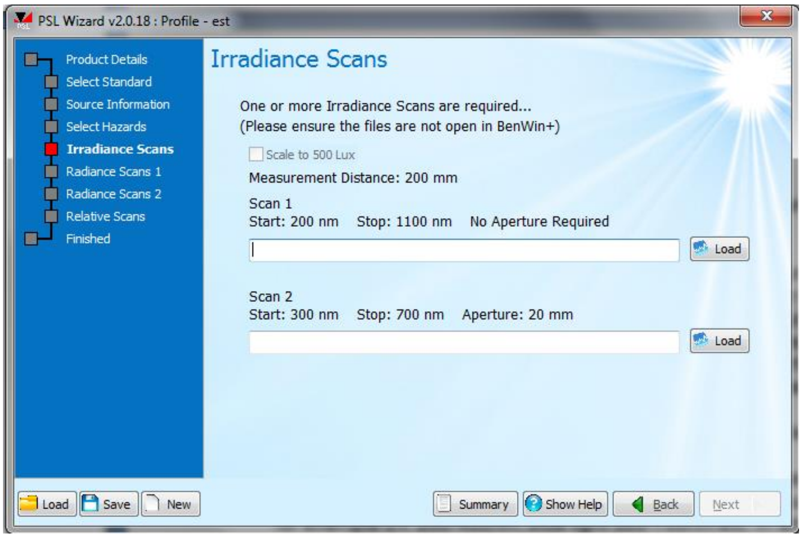
7.4 Applying Calibration
Where only one calibration lamp is used:-

- Go to scan/ data correction
- Load certificate file for CL6/ CL7 as required
- For system file, load just- saved system measurement of calibration lamp (average)
- 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 measurement s of spectral irradiance using the same custom wavelength files as that used for calibration

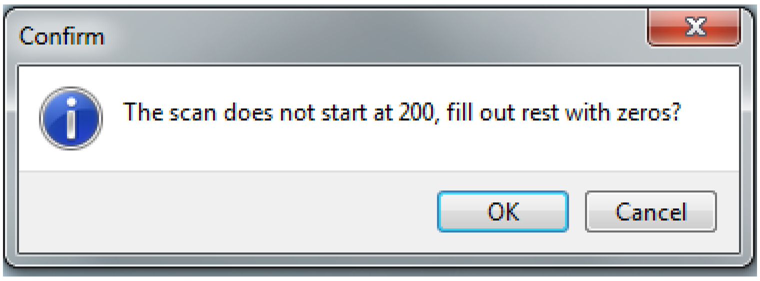
Where both calibration lamps are used (ensuring files not open in BenWin+):-

- 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 200-1100nm custom wavelength file
- The system is ready to perform measurement s of spectral irradiance

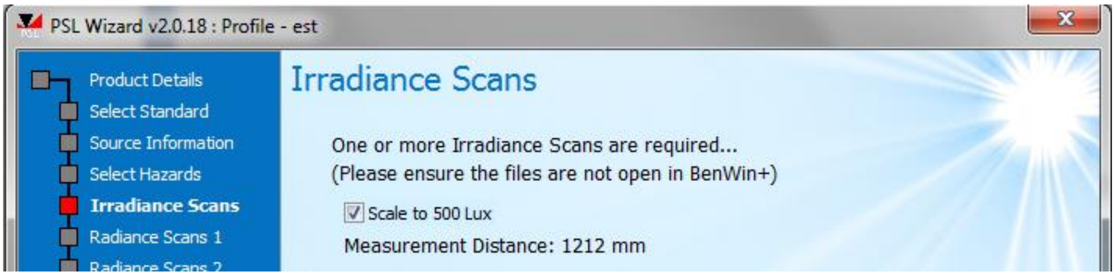
7.5 Source Measurements
- Perform measurements as prompted by the PSL wizard



- Where the PSL Wizard requests a limited measurement range, one can still load full range files 200-1100nm or 300-110nm
- Where a measurement is requested down to 200nm, but the decision was made by the use only to measure 300-1100nm, then the user will be prompted that the region 200-300nm will be "filled with zeros", ie the integration truncated



- In the case of GLS sources, it is recommended to perform measurements at a convenient working distance rather than the 500 lux distance. Where a suitable working distance be employed, check the scale to 500 lux box on the irradiance page (available for GLS only).



- Following this rationale, it is suggested for GLS source to perform the measurement where possible at 200mm. In this manner a dual GLS/ non-GLS analysis may be made.
- In the case of non-GLS sources, position the source at correct measurement distance from the (apparent) source
- Perform alignment for maximum signal via utility/ alignment utility at a suitable wavelength
- 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)

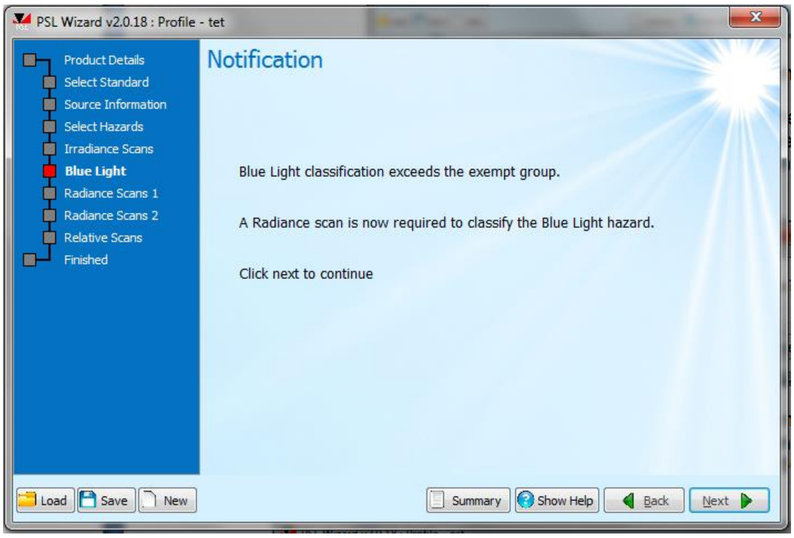
In the case of GLS sources, where a measurement distance of 200mm is employed, the apertures reported by the PSL wizard will not be correct since they are the apertures required at the 500 lux distance to limit the field of view. In the case of GLS sources, it is recommended not to apply apertures in any case.

In the case of non-GLS sources, where an aperture is required to limit the output of the source to 1.4 radians with regards the skin hazards, this should be put in place in front of the source and the measurement result loaded. This is a little encountered eventuality since most sources will subtended a smaller angle than this.

In the case of non-GLS sources, where an aperture is required to limit the output of the source to 100mrad in the consideration of blue light hazard exempt risk group it is recommended to use the DIFF_D7_FOVL with the aperture for 100mrad.

In the case of non-GLS sources, where an aperture is required to limit the output of the source to 35mrad in the consideration of retinal thermal weak visual stimulus hazardd exempt risk group it is recommended to use the DIFF_D7_FOVL with the aperture for 35mrad.

The UV hazards will be evaluated and classified directly. If the blue light exempt risk group is passed, a radiance measurement will be required only if the retinal thermal hazard is selected. If the blue light exempt risk group fails, the user will be prompted to this fact and measurements of radiance required.



7.6 DIFF_D7_FOVL

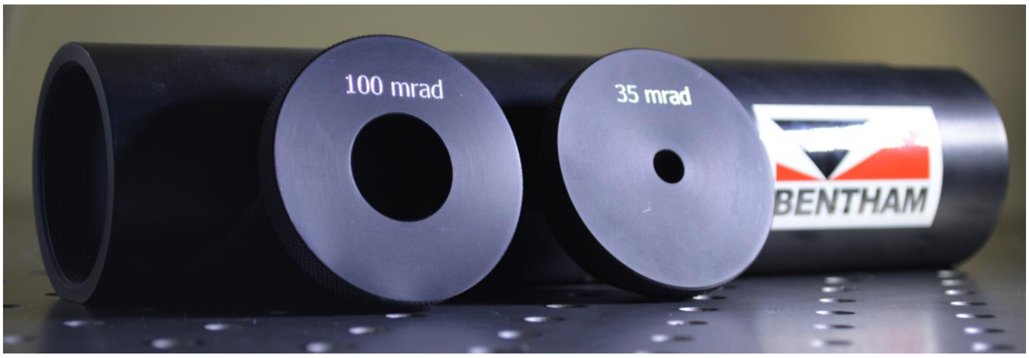


Figure 9: DIFF_D7_FOVL

The DIFF_D7_FOVL is a baffle tube designed to adapt to the the D7 cosine diffuser, and supplied with two interchangeable apertures to allow performing measurements in 100mrad or 35mrad. The length of the baffle tube is such that when touching the source, the front surface of the D7 diffuser will be placed at 200mm from the source as required in the consideration of non-GLS sources.

The D7 diffuser fits to one end of the DIFF_D7_FOVL and held in place using an M6 screw provided. There is no need to re-calibrate in using the DIFF_D7_FOVL.

The DIFF_D7_FOVL is supplied with an optical post mounting system but can equally be placed on a lab jack or mounted using a tripod.

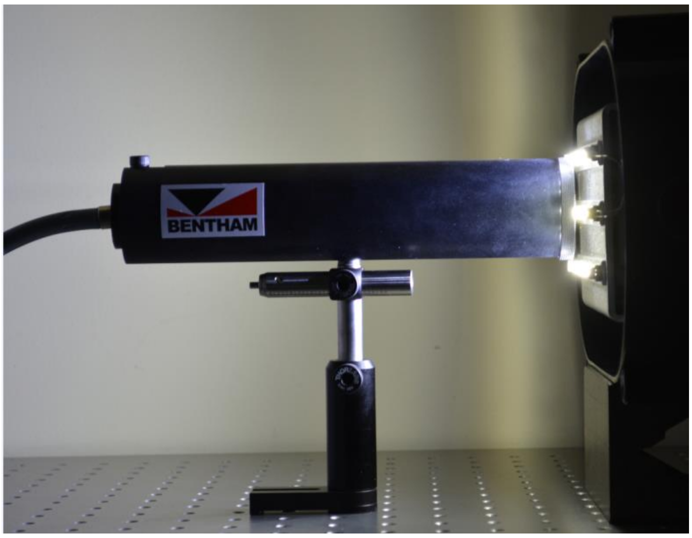


Figure 10: DIFF_D7_FOVL in use

8. Radiance Measurement

The measurement of radiance is required where a source fails the blue light exempt group and for the determination of the retinal thermal hazard.

The TEL309 permits measurement of radiance in key 11 and 1.7mrad FOVs only. It is generally recommend to use the TEL309 for non-GLS sources only, at 200mm. Whilst the measurement of GLS sources may be performed at their respective GLS distances, for each GLS distance a new calibration will be required, which constitutes a significant work load. It can be shown that in the majority of GLS cases, the source will be blue light exempt by the previous measurement and can be shown to be retinal thermal exempt by calculation. The guidance here shall consider a measurement at 200mm.

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, “radiance11mrad.dat”, 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.

8.1 Hardware Setup

- IDR300-PSL with PMT, Si, InGaAs
- 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 610 supply

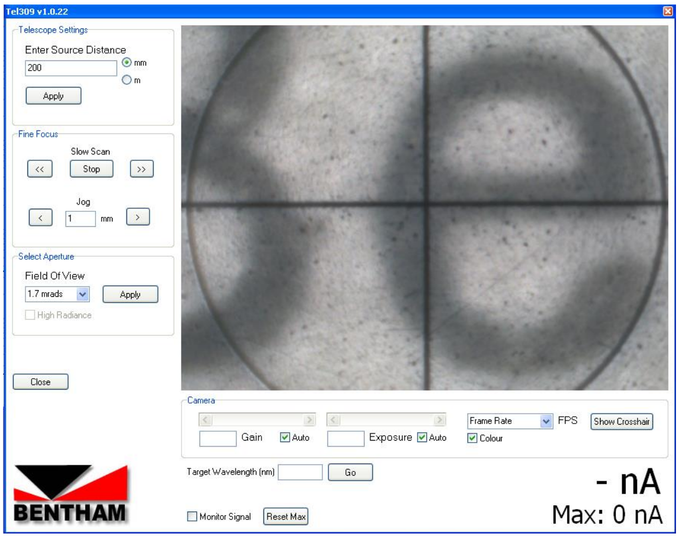
Figure 10: TEL309

8.2 Software Setup

- Initialise BenWin+ in the radiance configuration

8.3 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 610 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

11mrad calibration

- 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 “radiance11mrad.dat” 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 scan, go to analysis/ spectral average, hit ok to take average of all scans
- Go to analysis/ delete spectra, select original measurement to delete, leaving average
- 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)

It is recommended to calibrate the 1.7mrad FOV in case the source fails the RG1 blue light/ retinal thermal exempt risk group.

1.7mrad calibration

- In the TEL309 window, select 1.7mrad
- Go to Scan/ Scan setup, go to advanced
- Ensure that the “radiance1_7mrad.dat” 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 scan, go to analysis/ spectral average, hit ok to take average of all scans
- Go to analysis/ delete spectra, select original measurement to delete, leaving average
- 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 (1.7mrad here) in name to indicate the nature of measurement)
- Power off SRS12 and allow one minute cool-down time prior to moving lamp

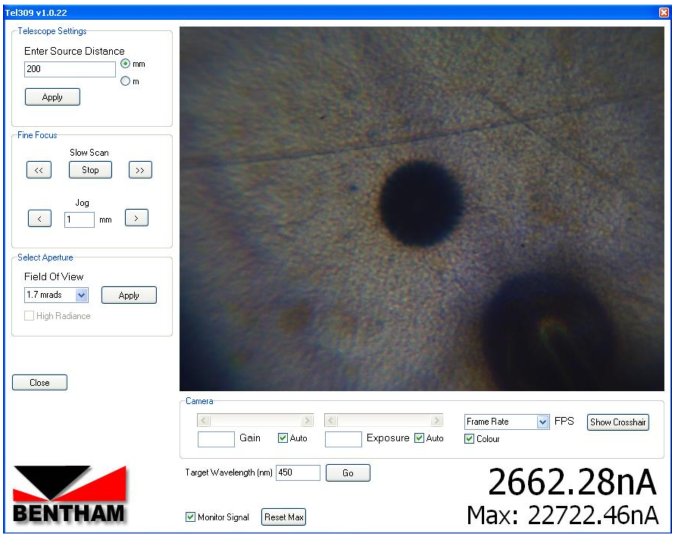
8.4 Applying Calibration

In turn calculate correction factors for 11mrad and 1.7mrad in data correction, starting with 1.7mrad first to ensure the system is ready for an 11mrad measurement:-

- Go to scan/ data correction
- There should be no need to load certificate file (if not selected, load SRS12 certificate file)
- For system file, load just- saved system measurement of calibration lamp with 1.7mrad FOV
- Hit calculate calibration data
- On prompt say OK to the application of data correction forthwith
- Save calibration data for future reference
- Load system file of measurement of calibration lamp with 11mrad FOV
- Hit calculate calibration data
- Save calibration data for future reference
- The system is ready to perform measurements of spectral radiance with 11mrad FOV

8.5 Source Measurements

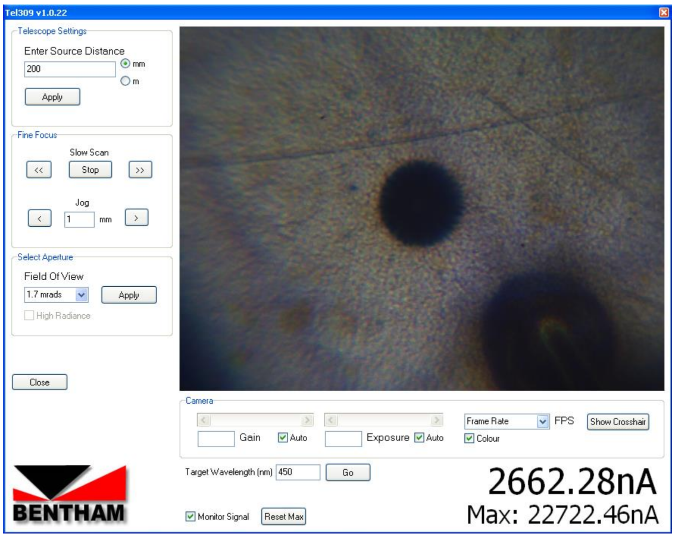
- Go to utilities/ TEL309
- In the TEL309 window, for the purposes of alignment, select 1.7mrad
- At the bottom of the page, input a target wavelength at which to perform alignment and hit monitor signal. The current and maximum values will be reported



1.7mrad aperture selected

Signal monitor

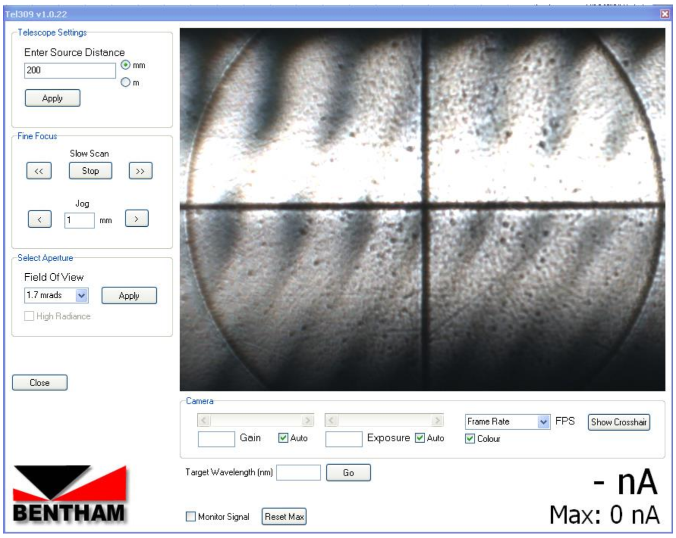
- Position source to get it into **focus** on the TEL309 camera- what is sought is what the eye would view, LED chip, diffuser, etc. In many instances it is not clear what is being looked at!
- Where the source incorporates a diffuser with nothing to focus on, it may be useful to place a business card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



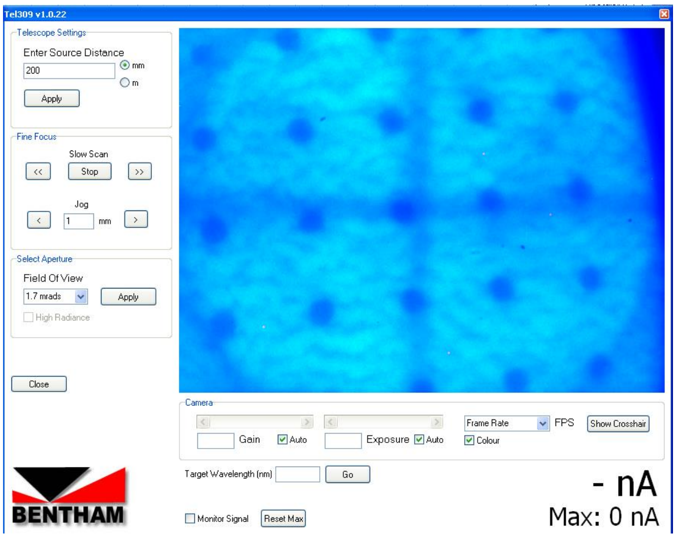
White PC-LED chip- the phosphor acts as a diffuser so it is not clear what is being viewed other than the grid of electrical connections and the wire bond

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

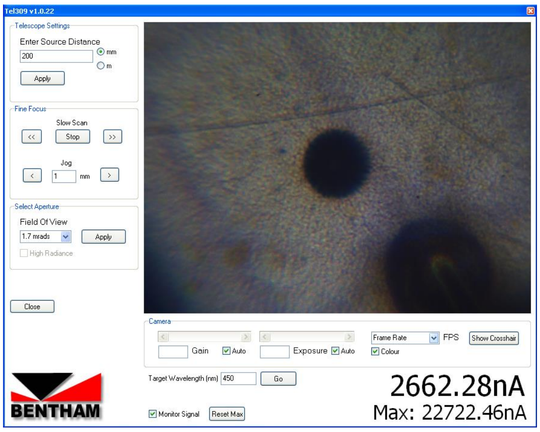


Contrary to the case of PC-LEDs, coloured LEDs do not have a diffusing phosphor layer so one can see the chip very clearly

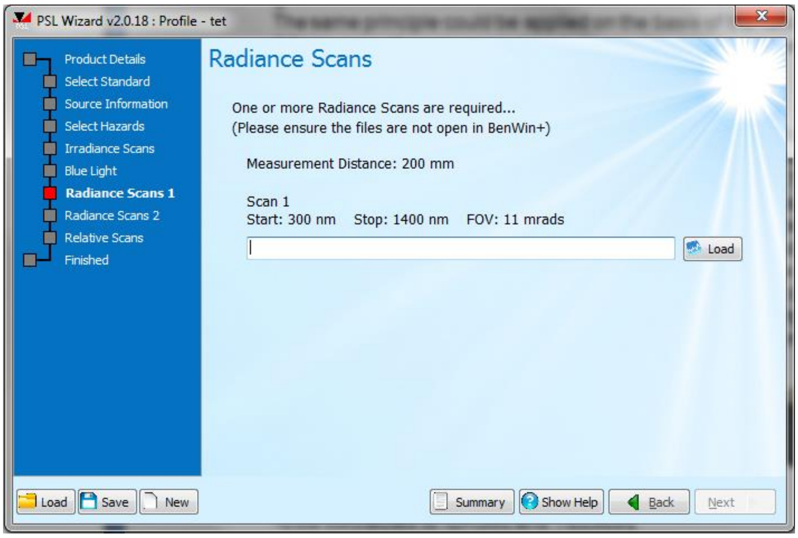
- The key to this process is moving large amounts to determine what is being viewed and having in mind that the full view of the CMOS camera at 200mm is ~2.2mm at the source

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

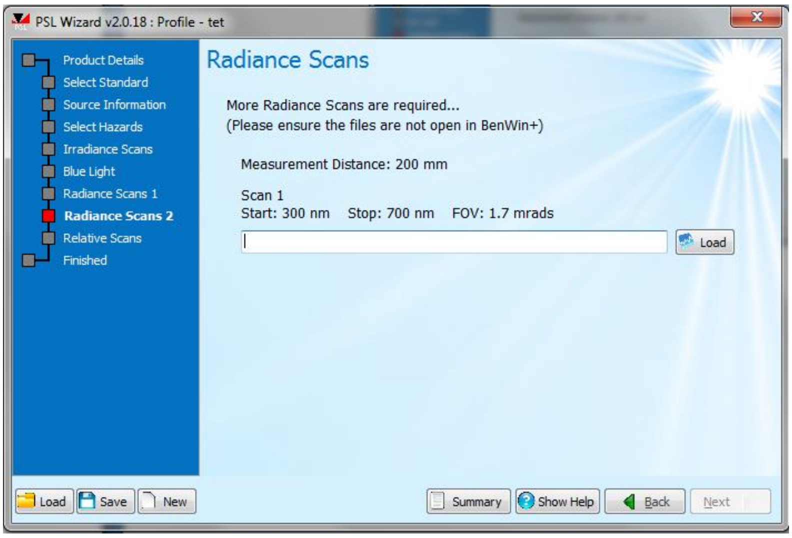
- Optimise source position for maximum signal, and try to centre source on screen so that it will be central to the 11mrad FOV when selected
- Where the signal level saturates the CMOS camera in the TEL309, the 7mm aperture can be placed in the TEL309 lens to reduce signal ***(ensure this is removed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



- Where the RG1 radiance limits are exceeded, the user will be prompted to perform measurements in 1.7mrad FOV

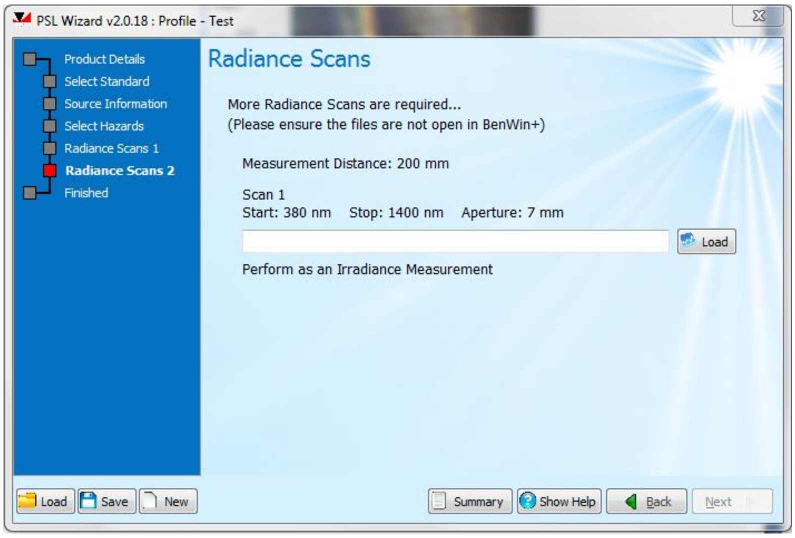


- Go to scan/ data correction load calibration data and load calculated calibration file for 1.7mrad
- Go to utilities/ TEL309
- In the TEL309 window, select 1.7mrad
- Adjust source position whilst seeking a maximum signal through the alignment function to the bottom of the page
- Close TEL309 and perform new scan
- Save result, giving appropriate name (it is recommended to include reference to radiance and the field of view (1.7mrad here) in name to indicate the nature of measurement)
- Close measurement in BenWin+
- Pass result to PSL-Wizard
- End of radiance measurements

8.6 Retinal Thermal Weak Visual Stimulus
Where the luminance in 11mrad FOV is determined to be <10 cd m^{-2}, the retinal thermal hazard adopts another set of limits, the weak visual stimulus limits, to account for the fact that with the lack of visual stimulus, the pupil will be fully dilated (7mm) and more light will enter the eye. The retinal thermal weak visual stimulus limits are lower than the retinal thermal limits.

Furthermore, the time basis of the retinal thermal weak visual hazard is 1000s exposure for exempt, 100s for RG1 and 10s for RG2. The corresponding FOV of measurement is therefore 35mrad and 11mrad. Since the former cannot be performed with the TEL309, recourse to an irradiance measurement is required. Since all such sources would by definition be non-GLS sources, with 200mm measurement distance, an aperture of 7mm diameter should be placed in front of the source and the source irradiance measured. This can be achieved in using the DIFF_D7_FOVL as described in section 7.6.

This case defeats the natural sequence of the PSL wizard, going from irradiance to radiance measurement, requiring a return to the irradiance configuration. The user shall be prompted by the PSL wizard if this action is required.



8.7 Discussion

It should be noted as a check to correct measurement and alignment that by the nature of the measurements, the blue light radiance results in the various FOVs should follow the following behaviour, where the equality only applies for a uniform source that overfills all three FOVs:-

$$L_{B,\ 100mrad} \leq L_{B,\ 11mrad} \leq L_{B,\ 1.7mrad}$$

9. Infra Red Measurement

The infra red measurement permits evaluation of the infra red skin hazards. It is recommended that above 1100nm, rather than perform measurements of spectral irradiance, measurements of relative spectral output should be made due to limitations of the AC configuration.

9.1 Hardware Setup

- IDR300-PSL with PbS detector AC electronics, relay optic and chopper, and BenWin+ AC configuration.
- CL6 calibration lamp with 610 supply

9.2 Software Setup

- Initialise BenWin+ in the infrared configuration

9.3 Calibration Measurement

- Position CL6 at 200mm from front face of relay optic
- Set up CL6 irradiance standard, connect red and black cables and fan
- Ensure current of 610 set to 6.3A, power on, allowing 5 minutes warm-up period
- Go to Scan/ Scan setup, (scan range should be defined 1000 to 3000nm, if not go to advanced, check use custom wavelength file, and load infrared)
- 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, save, giving appropriate name
- Power off CL6 and allow one minute cool-down time prior to moving lamp

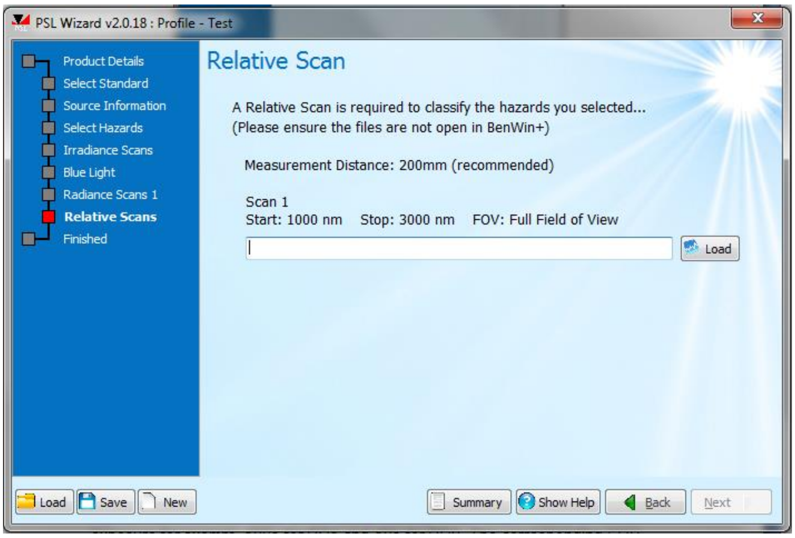
9.4 Applying Calibration

- Go to scan/ data correction
- There should be no need to load certificate file (if not selected, load extended version of CL6 certificate file)
- 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 measurement s of relative spectral output

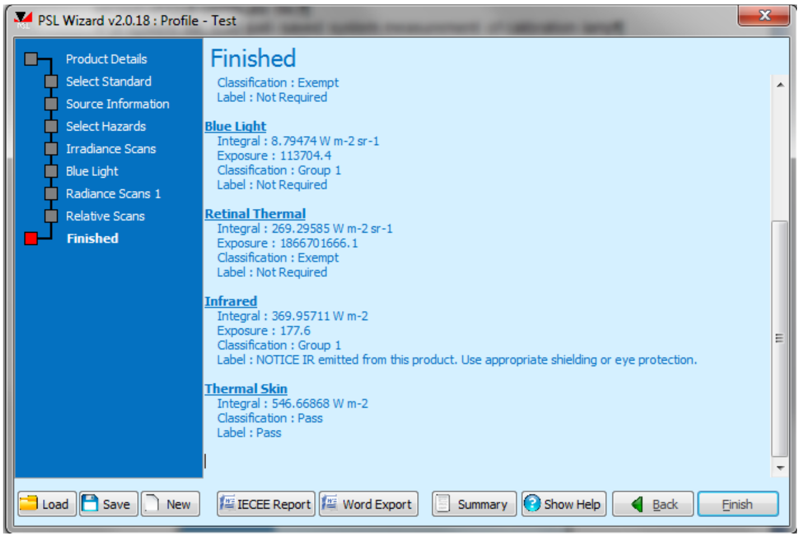
9.5 Source Measurements

- Position the source under test at a similar position to that of the CL6 (200mm distant and central to relay optic)
- Hit new scan and save file
- Pass the measurement result to the PSL wizard. This relative measurement, 1000-3000nm will be used to extend the existing irradiance measurement result up to 1100nm.



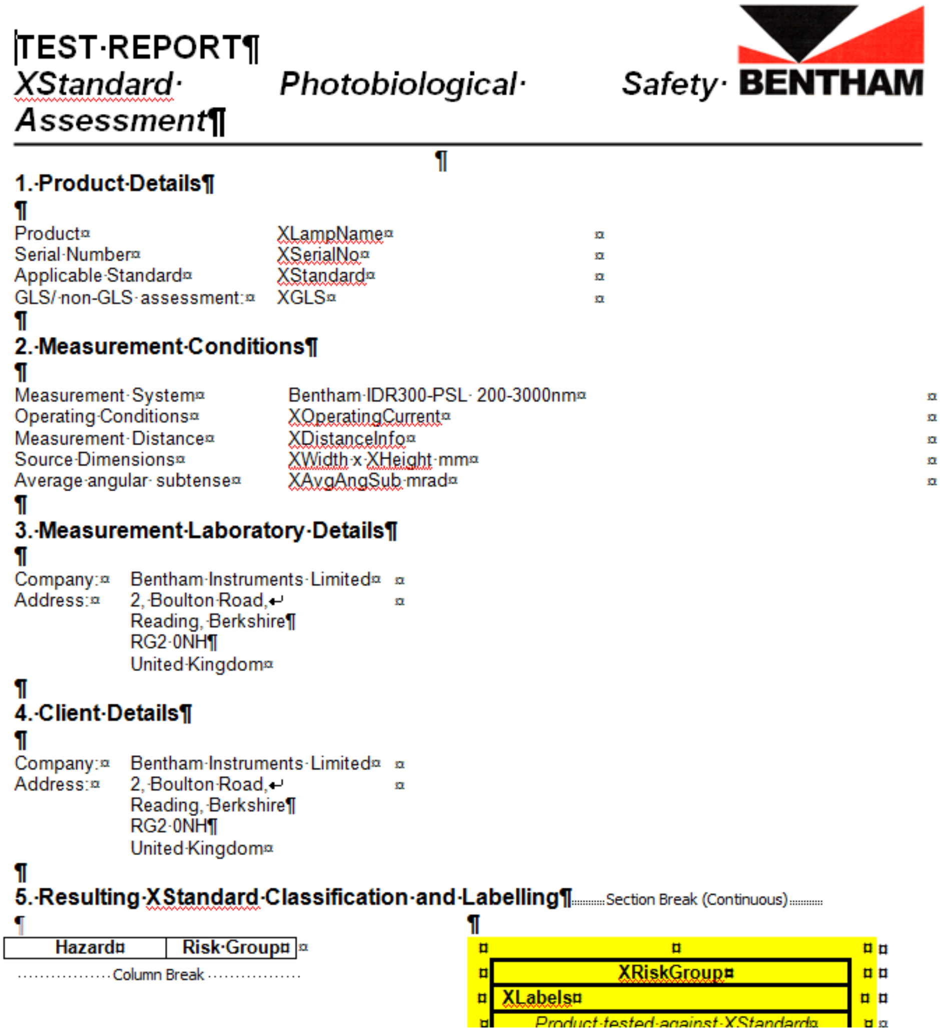
10. Reporting Results

The measurement procedure has now been finished, continuing with the PSL wizard takes one to the reports page.



One can either copy the results directly from here, or hit export to IECEE report or to Word report. In the former case, table 6.1 of an IECEE IEC62471 test report is filled out. In the latter case, results are exported to a customisable template, of which there are two versions- one for use with the PSL profiler, and one used when the profiler is not used.

These files are to be found in the Bentham/ PSL wizard/ Templates folder location. The PSL wizard searches for those components prefaced by an “X”- these should not be changed. Logo, format etc may however be modified.


TEST REPORT

XStandard Photobiological Safety Assessment

BENTHAM

1. Product Details

Product	XLampName
Serial Number	XSerialNo
Applicable Standard	XStandard
GLS/ non-GLS assessment:	XGLS

2. Measurement Conditions

Measurement System	Bentham IDR300-PSL 200-3000nm
Operating Conditions	XOperatingCurrent
Measurement Distance	XDistanceInfo
Source Dimensions	XWidth x XHeight mm
Average angular subtense	XAvgAngSub mrad

3. Measurement Laboratory Details

Company:	Bentham Instruments Limited
Address:	2, Boulton Road, Reading, Berkshire RG2 0NH United Kingdom

4. Client Details

Company:	Bentham Instruments Limited
Address:	2, Boulton Road, Reading, Berkshire RG2 0NH United Kingdom

5. Resulting XStandard Classification and Labelling Section Break (Continuous)

Hazard	Risk Group

Column Break

XRiskGroup

XLabels

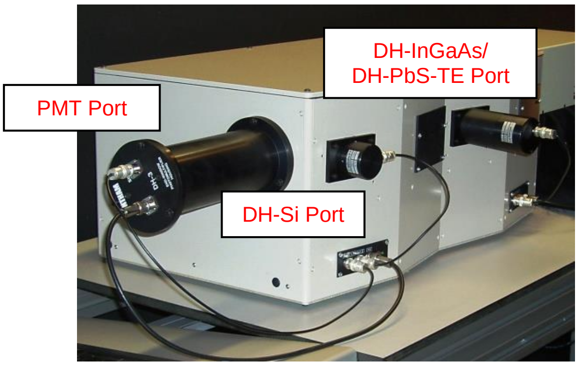
Product tested against XStandard

Appendix 1: System Installation

The following notes are provided for initial system installation and to assist when using the system and migrating between configurations.

Monochromator
The monochromator should be sited in a suitable location. Only handle the IDR300 from the base of the unit- never use connected detectors as handles. When mounting detectors and the input optic to the IDR300, ensure that the correct length of screw is used. This ensures no damage to the motorised slits. See section on detectors, below.

Detectors
The system is supplied with four detectors (a DH-3 photomultiplier, and DH-Si Silicon, DH-InGaAs InGaAs and DH-PbS-TE PbS
The IDR300 has one entrance slit and three exit slits, one on the first monochromator and two on the second.



The DH-3 is installed on the port opposite the entrance slit; the DH-Si to the port adjacent to this slit and one of DH-InGaAs/ DH-PbS-TE is installed on the exit slit of the first monochromator.

The DH-3 is adapted to the exit slit via an adaptor fitted to the slit.

Using the long M4 allen key provided, the DH-3 is fitted to the adaptor ensuring that the rubber O-ring on the outside face of the DH-3 is in place, and the screw tightened firmly to avoid any light leaks.

All other detectors are directly attached to the exit slits with M3 screws provided.

It should be noted that the correct length of M3 screw should be used to avoid damage of the motorised slits. Suitable screws are provided, but for reference, before screwing in, only a few millimetres of screw should project.

IDR300 Electrical connections
The IDR300 requires a mains and a USB connection for operation. On connection to a computer for the first time, windows shall take a moment to recognise the device.

The connections for the DC detectors and lux meter are as follows:-

DH-3: High voltage connected from HV port on IDR300 to HV port on detector using thick BNC cable; signal port of detector connect to IDR300 input 1 using thin BNC cable. HV powered on using toggle switch, green LED indicates operation.

DH-Si: Detector connected to IDR300 input 2 using thin BNC cable.

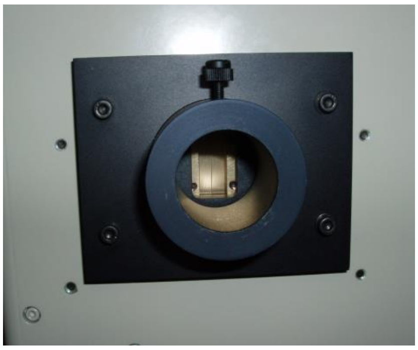
DH-InGaAs: Detector connected to IDR300 input 3 using thin BNC cable.

Luxmeter: Detector connected to IDR300 lux meter input.

Quartz Fibre Bundles
Both quartz fibre bundles are made such that on the input optic side they have a round ferrule and the monochromator side a rectangular ferrule to fit as closely as possible to the motorised slit.

These bundles are adapted to the entrance plate by an interface plate. Once the fibre is pushed in, it is held in place by a thumb screw.
The bundle should be pushed in such that silver coloured ferrule does not project from the adaptor.

The bundle should only be installed after initialisation of the system, when the motorised slits are closed. This ensures that the installed bundle does not impinge on the movement of the slits.

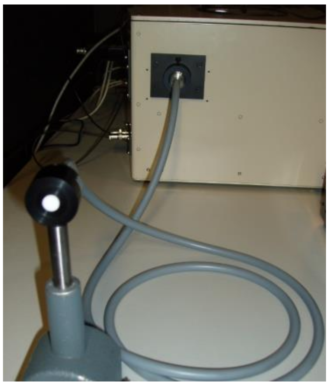


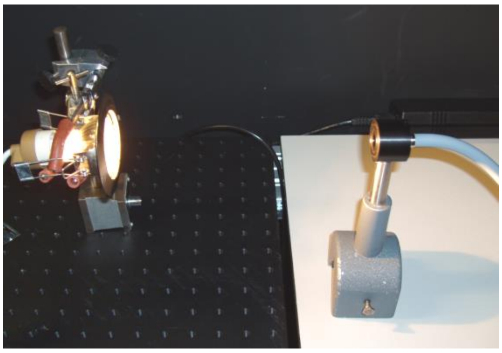
D7 Cosine Diffuser Input Optic
The D7 input optic permits the measurement of absolute irradiance; the spectral check input optic is based on the body of the D7, but having no PTFE insert is used only as a high throughput manner of measuring the relative spectral output of sources.

On the side of the spectral check and the D7 diffuser input optics, the quartz fibre bundle ferrule is pushed inside the body of the optic and held in place with a grub screw. Both optics have an M6 threaded hole to one side for mounting on a post.

In use, the D7 should be calibrated with the CL6 and/or CL7 and measure sources at a distance from the front of the white PTFE of the diffuser.

The spectral check optic should be calibrated with the CL6 and measure sources at 200mm.

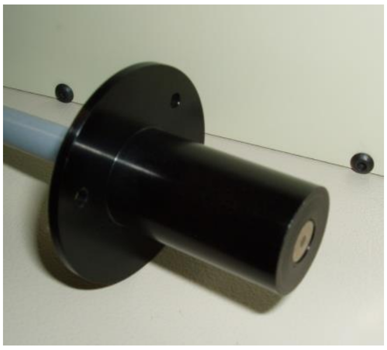




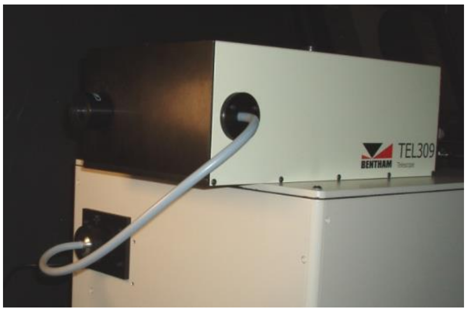
TEL309 Telescope
It is recommended to install the TEL309 on top of the IDR300 due to the short fibre in use.

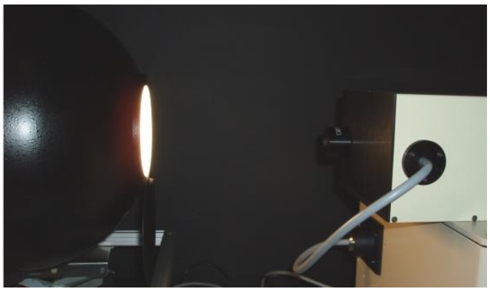
The TEL309 requires a mains power and USB connection. Please follow instructions in the section on software for installation of the USB camera drivers.

The fibre of the TEL309 is adapted on one side to the entrance port of the IDR300 and on the other side is fitted with an adaptor for attachment to the TEL309. The position of the fibre should be such that mechanical stress is minimised.



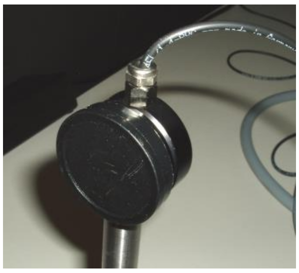
In use, the measurement distance used is the one between the entrance lens of the TEL309 and the source under consideration.



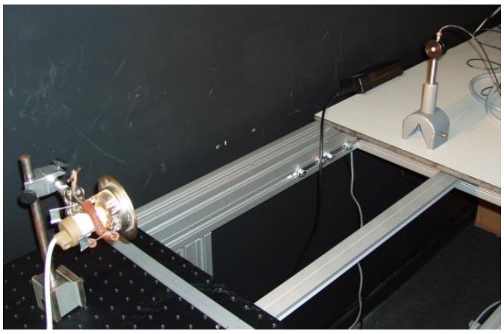


Lux Meter
The lux meter is used to determine the 500lux measurement distance of GLS sources.

Where required, the cover should be put in place to perform dark current measurements. The device is provided with an M6 threaded hole for mounting to a post.

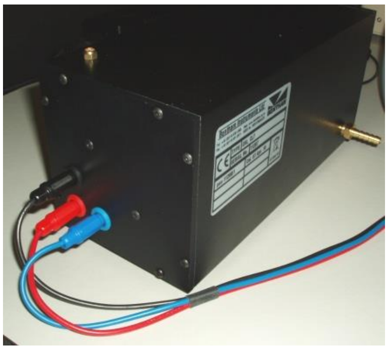


In use, with the correct alignment, the measurement distance is varied to obtain 500 lux, and the measurement distance recorded from the front surface of the lux meter to the reference point on the source.



Calibration Standards
This system comprises three calibration standard, CL7, CL6-H and SRS12.

The deuterium standard of irradiance is operated by the 706 power supply.



Connect red, black and blue connections correctly and power on the source. A heater is applied for a short time at the end of which the blue starter LED illuminates and a high voltage ionises the gas in the lamp permitting the flow of current and lamp output. A blue LED “lamp” indicates operation of the source. The source is simply powered off by the on/ off switch.

The CL6-H is a quartz halogen standard of spectral irradiance, operated by the 610 constant current supply at 6.3A.

Connect red, black and fan cables, ensure the current is set to 6.3A and power on.

After the five minute warm up period, it is useful to note the voltage on the front panel of the 610 for reference.

In use, the irradiance calibration of both the CL7 and CL6 are provided at 5.5mm from the front face, a distance set by the DAR adaptor screwed into the front of the source.

The diffuser should be pushed in and held in place using the thumb screw.

The SRS12 is a quartz halogen standard of spectral radiance, operated by the 610 constant current supply at 8.5A.

Connect red, black cables, ensure the current is set to 8.5A and power on.

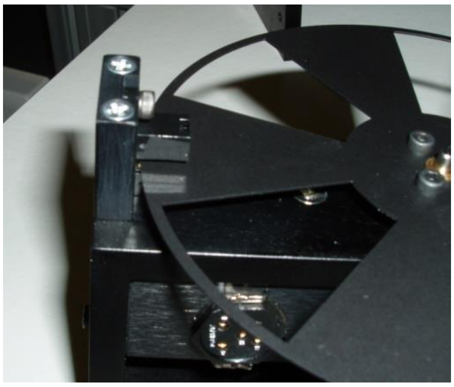
In use, the output port of the SRS12 is used as a uniform standard of radiance; one images therefore the plane of the port of the SRS12 in measurements, the measurement distance is from the lens of the TEL309 to the plane of the port.

AC Measurement Setup

Measurements in the infrared require a different input optic and the use of the DH-PbS-TE detector.

The relay input optic consists of a lens assembly and a mount for the optical chopper.

To the optical chopper should be fitted the 5-slot blade, and held in place by the three central screws. Care should be taken to ensure that the blade passes through the opto at the base of the chopper.

The mount of the optical chopper is attached to the barrel of the relay optic in such a manner that the blade runs free on the provided groove.

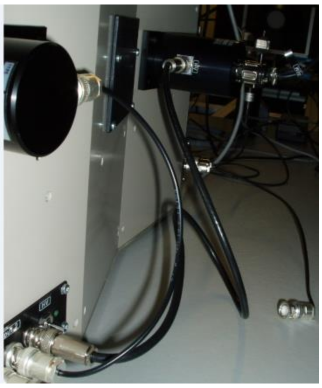
The DH-InGaAs detector should be removed and replaced with the DH-PbS-TE.

The 417 detection electronics should be sited in a suitable location, and connected to mains and USB and powered on.

The electrical connections are as follows:-

-Connect 218 chopper controller to chopper using 5 pin cable

-Ensure reference output of 218 is connected to the reference port of the 496 lock-in
-Connect CPS1M to detector rear port using 5-pin connector
-Remove HV cable from PMT and attach to PbS detector HV port
-Connect detector signal port to input 1 of 477 amplifier



Ensure 218 chopper controller and CPS1M both powered on.

Set the optical chopper to obtain a chopping frequency of 175 or 225 Hz (218 dial reads correctly for 10 slot blade, scale for other blades (eg. 5 slot blade 175 Hz obtained with 350 Hz on dial). Otherwise one can adjust and read the frequency from the display of the 496 lock-in.

The output of the 477 amplifier should be connected to input one of the 496 DSP lock-in amplifier

It is recommended to use the AC input optic as a measurement of relative spectral shape in the infra red, to this end all measurement should be made at 200mm from the optic.