BENTHAM

IEC 62471-5 Photobiological Safety of Lamps and Lamp Systems: Image Projectors

1. Introduction

This document is written to guide users of the Bentham IDR300-PSL system through the measurement procedure required to evaluate image projectors against 62471-5.

IEC 62471-5: 2015 provides a risk group classification system for image projectors ad measurement conditions for optical radiation emitted by image projectors. This particularly applies to laser illuminated projectors (LIPs) given that according to clause 4.4 of IEC 60825-1: 2014, where unweighted radiance measurements (400-1400 nm) in 5 mrad FOV at 200 mm < 1 $MW \cdot m^{-2} \cdot sr^{-1} / \alpha$ (α limited to 0.005 – 0.01 mrad) then IEC 62471 series can be applied.

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, IEC 62471-5, EN 62471-5, ANSI RP27, JIS C 7550 and the European Union Artificial Optical Radiation Directive (AORD), 2006/25/EC.

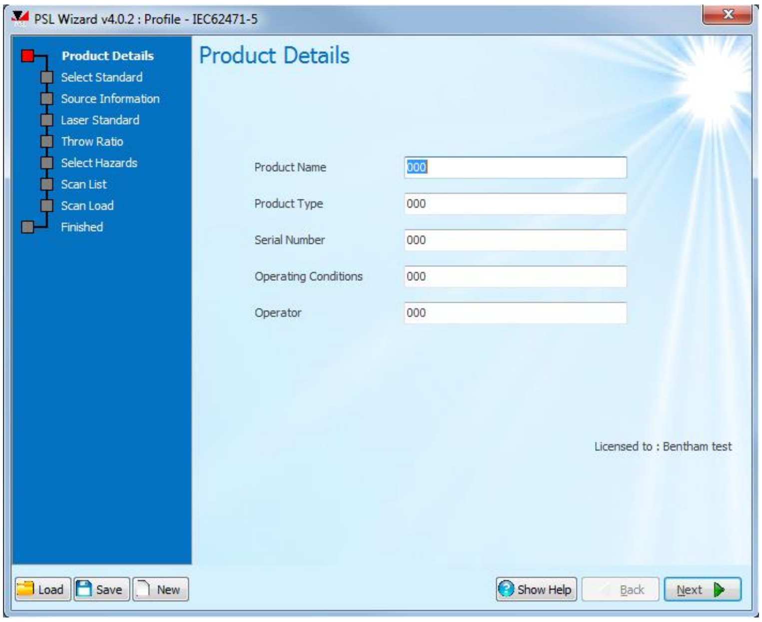

Figure 1: Product Details page of the PSL Wizard

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. Procedure

To measure projectors against IEC/EN 62471-5 users should fill out the pages and follow the instructions laid out in the PSL Wizard. Start by selecting the standard to measure image projectors, this being IEC 62471-5 and EN 62471-5.

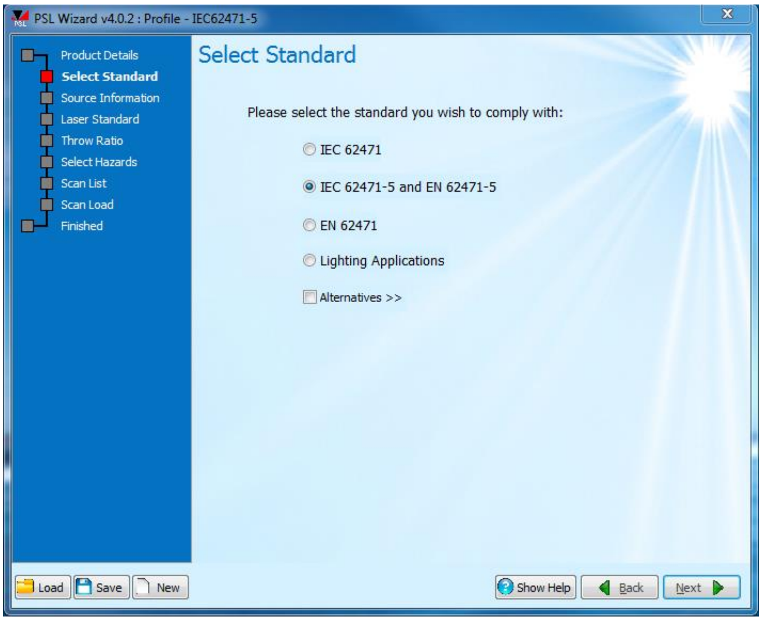

Figure 2: Standard Selections page in the PSL Wizard.
In this in case IEC 62471-5 should be selected

3.1 Projector Source Information

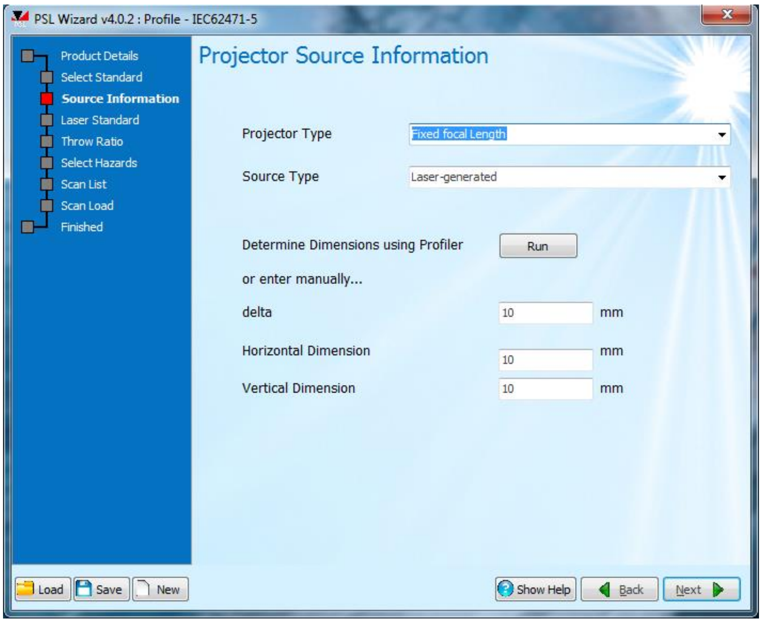

Figure 3: Projector Information page in the PSL Wizard. Projector and source type should be selected from the drop down and dimensions should either be entered manually or measured using the PSL Profiler

It is now necessary to input the source information. For the projector type the user has to choose between fixed focal length, non-interchangeable lens and interchangeable lens. The source type should also be chosen and the user has the choice of tungsten halogen, discharge lamp, LED and laser-generated. If known then the delta, the distance between the source and the closest point of human access (CPHA) and the source size (X and Y) can be entered. If these are not known then it is necessary to use the PSL Profiler.

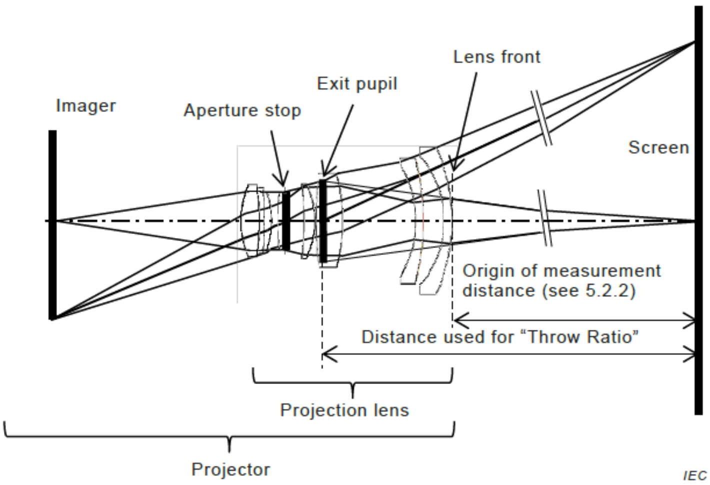

Figure 4: Schematic of a projector

3.1.1 PSL Profiler and Image Projectors

- 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 at the CPHA, 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

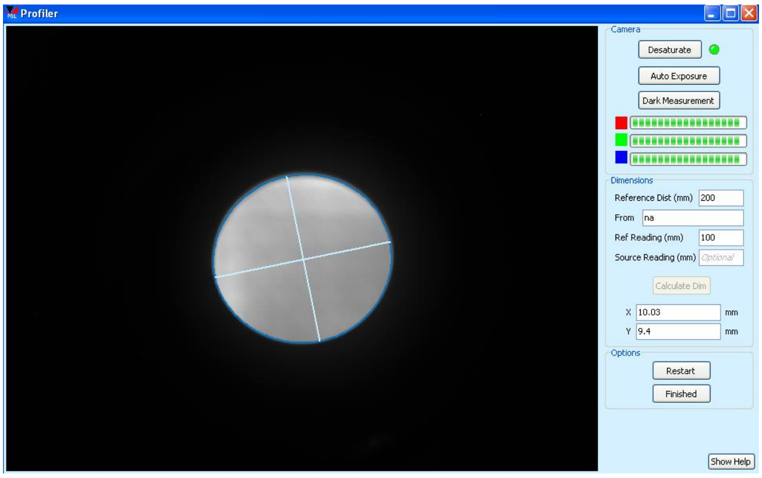

Figure 5: Saturated view of light source using the PSL Profiler

- 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 pre-set 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.

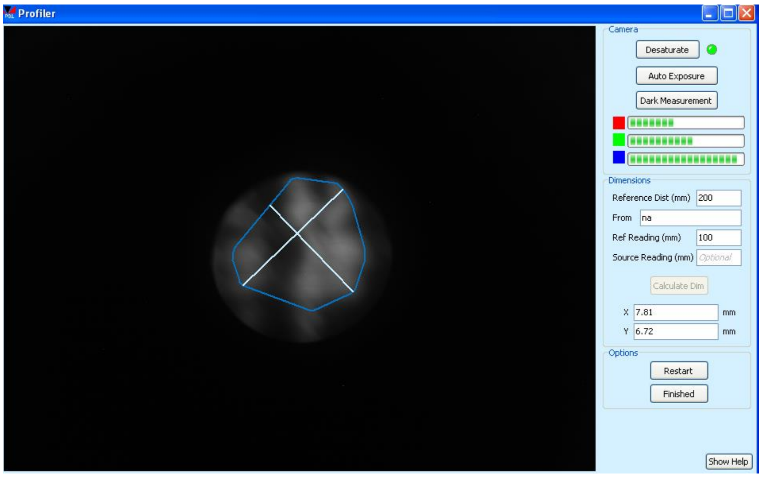

Figure 6: Desaturated view of a light source using the PSL Profiler

- 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.

3.2 Laser Generated Projector Standard Check

If laser-generated was selected as the source type on the projector information page then users will be taken to the page shown below.

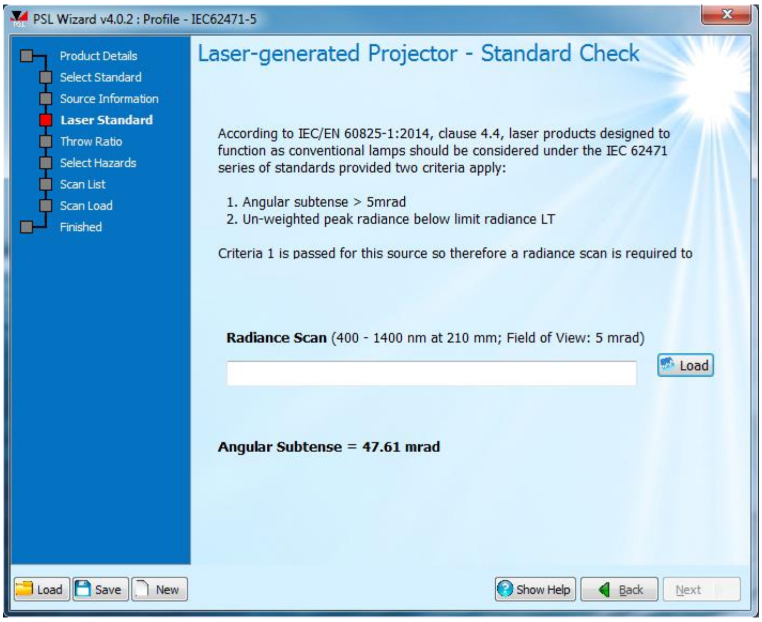

Figure 7: Laser-generated Projector Test Page. This checks to see whether a laser light source can be viewed as a conventional light source and measured against the IEC 62471-5 standard

Providing the angular subtense which is calculated from the x, y and delta values in the projector source information page, is less than 5 mrad users are prompted to perform and load a radiance measurement of the projector at 200mm to the CPHA (200mm + delta) at 5 mrad. If both criteria are passed then the user is allowed to pass on to the projector throw ratio page, otherwise users will be prompted to measure the DUT using IEC/EN 60825-1:2014.

3.3 Projector Throw Ratio

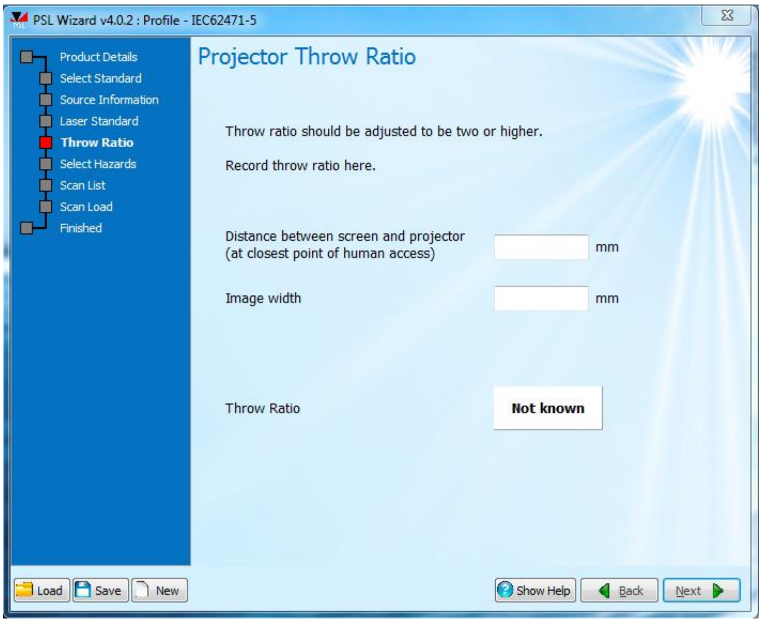

Figure 8: Throw ratio is calculated on this page from the pupil to screen distance and the width of the image

Throw ratio is defined as the ratio between the distance from the exit pupil to the screen and the width of the image. Fixed focal length projectors with no adjustable zoom should adjust the focus to maximise the radiance. Projectors with an adjustable throw lens that is not interchangeable should be adjusted to maximise the ratio between the radiance and AEL. Projectors with interchangeable lenses should be tested such that the throw ration is larger than or equal to 2.

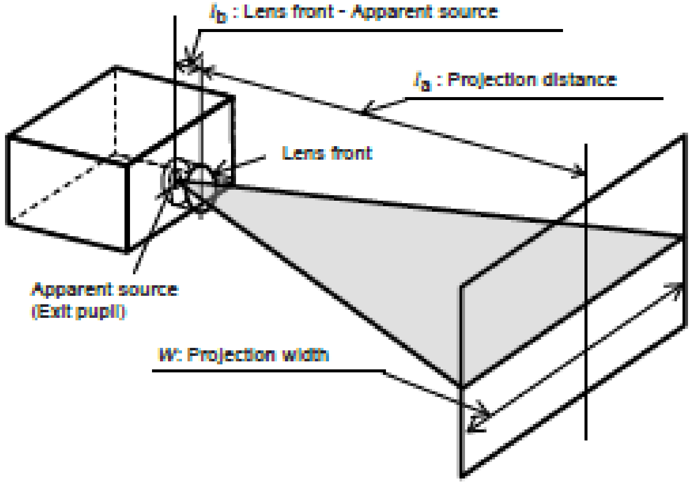

Figure 9: Diagram showing throw ratio of the projector

3.4 Projector Hazards

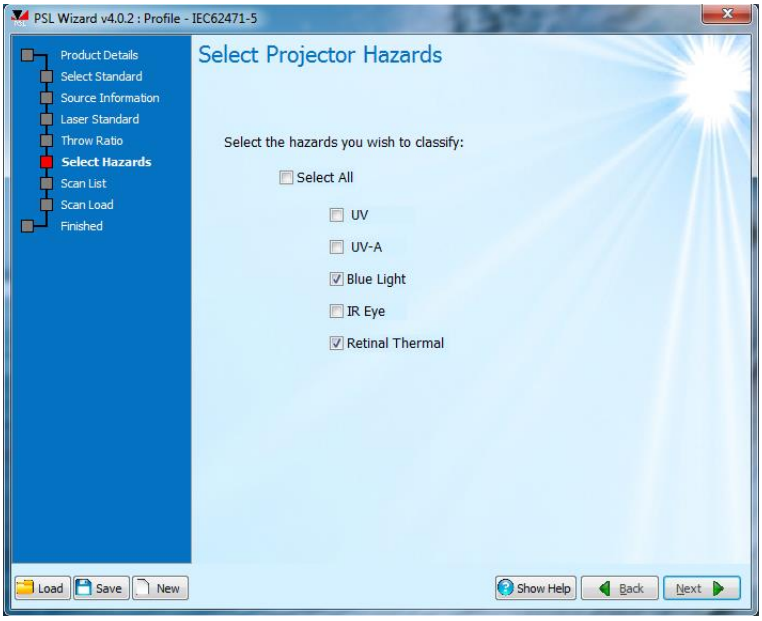

Figure 10: The hazard selection page allows the user to select the hazards to be measured

On the projector hazards page users are required to select the hazards that they wish to measure against. We recommend that users measure the blue light and retinal thermal hazards as a minimum but are also able to select additional hazards, these being UV, UV-A and IR Eye. After the scans are selected, the measurements that are required are listed on the next screen (shown below).

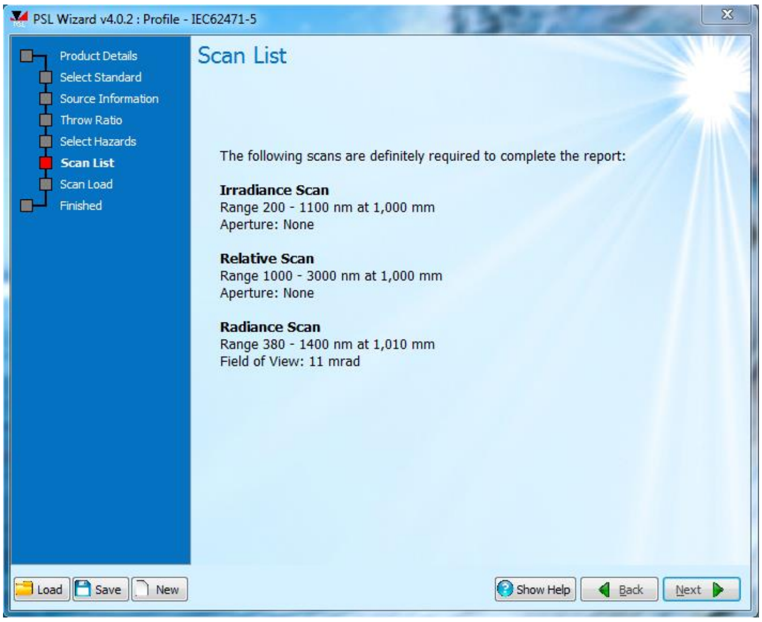

Figure 11: This page provides a list of measurements the user must perform in order to measure against 62471-5

The subsequent page asks users to upload scans dependant on the hazards selected (the page below shows the scans needed if all hazards are selected). The method for each measurement type is depicted in the ensuing section.

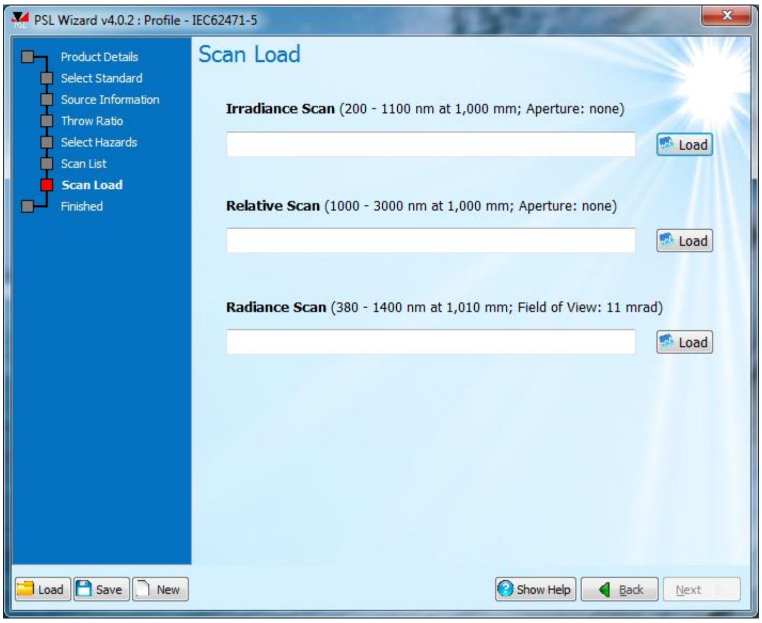

Figure 12: Users should use this page to load the scans that they performed according to the list on the previous page

After loading the necessary scans into the PSL Wizard and pressing next, the results of the analysis are shown (see below). From this page it is possible to export the results into a report and for them to be saved.

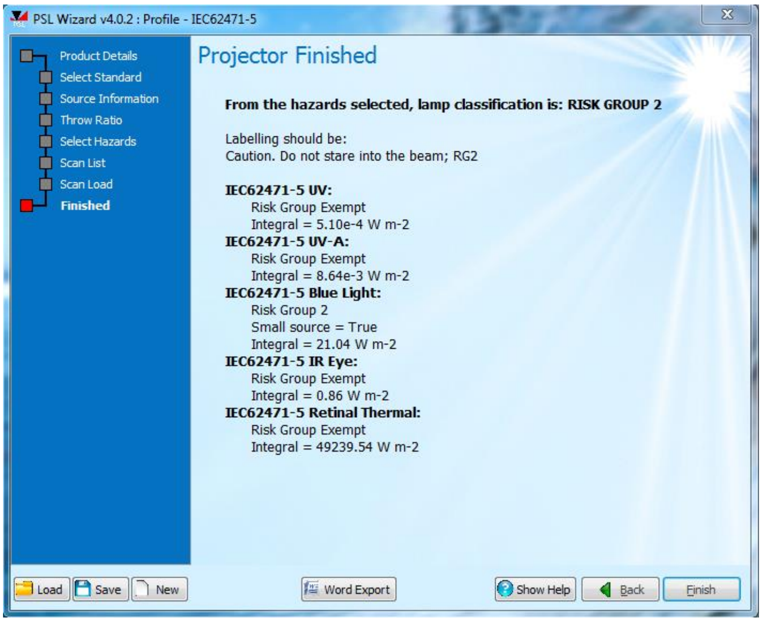

Figure 13: This page lists the group that is applicable for each hazard for the light source

4. Measurements

When performing measurements under IEC/EN 62471-5 users may want to use the Bentham Projector test pages to ensure that the worst case scenario is measured for each of the hazards. These are available as a PowerPoint presentation from our support page. For example, users may wish to try to measure the blue light hazard using the white and blue test pages and then use the worst case in the PSL Wizard.

4.1 Irradiance Measurements

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.

4.1.1 Hardware Setup

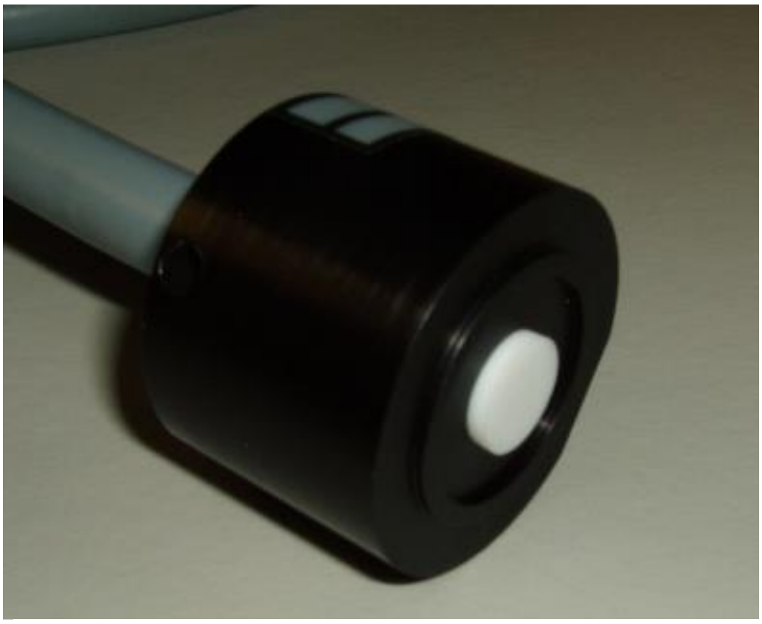

Figure 14: FOP-UV with D7 Cosine Corrected Input Optic

- 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

4.1.2 Software Setup

Initialise BenWin+ in the irradiance configuration

4.1.3 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

4.1.4 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 measurements of spectral irradiance when the projector's CPHA is set at 1m from the diffuser

4.1.5 Overload Conditions

Should users find that the measurement causes an overload condition at 200mm the user can still measure the lamp by performing the measurement as follows:

- When overload error message returned, hit OK and save measurement result
- Go to alignment utility and select a wavelength at which the source is not in overload (ie. a wavelength at which the previous measurement provides a result
- Note the photocurrent, A
- Move the sample to a greater distance, in the first casing to around a tenth of the value A, note new value, B
- Perform a spectral measurement at this new distance
- If measurement fails due to overload, repeat above procedure, increasing measurement distance to one hundredth of A, noting new value in alignment utility, C.
- At the end of the successful spectral measurement, go to analysis/spectral arithmetic,
- Current measurement OperandA, operation A x B, Select "replace OperandA", Operand B constant and input value of A/B (or A/C), hit OK

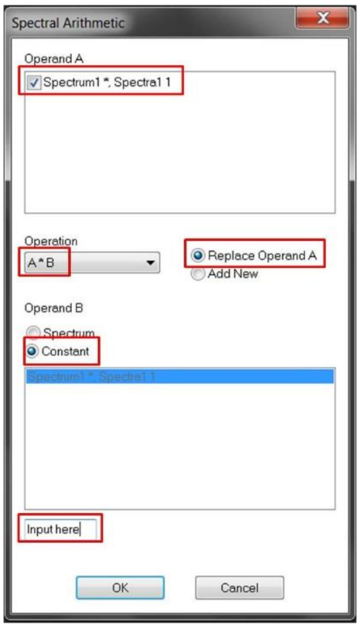

Figure 15: Spectral Arithmetic window used to calculate the adjusted irradiance during when an overload condition occurs

- Save the result
- Comparison of this spectrum with the truncated measurement performed at 200mm (using analysis/ overlay spectra, both spectrum files open in Benwin+), should show a good agreement.

4.2 Radiance Measurements

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 TEL309/310 permits measurement of radiance in key 11, 5 and 1.7mrad FOVs only. It is generally recommend to use the TEL309/310 for non-GLS sources only, at 200mm. While 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.

4.2.1 Hardware Setup

- IDR300-PSL with PMT, Si, InGaAs
- TEL309/310 with quartz fibre bundle and powered on
- **(if FOP-UV not connected to monochromator, do not do so until software initialised)**
- USB connected to IDR300 and TEL309/310
- SRS12 calibration lamp with 610 supply

Figure 16: TEL309 used for radiance measurements

4.2.2 Software Setup

- Initialise BenWin+ in the radiance configuration

4.2.3 Calibration Measurement

- Position SRS12 in front of TEL309/310, the final location of the SRS12 will be performed using the camera of the TEL309/310
- 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 Utility
- Input measurement distance (here 1m + delta), 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 TEL309/310 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

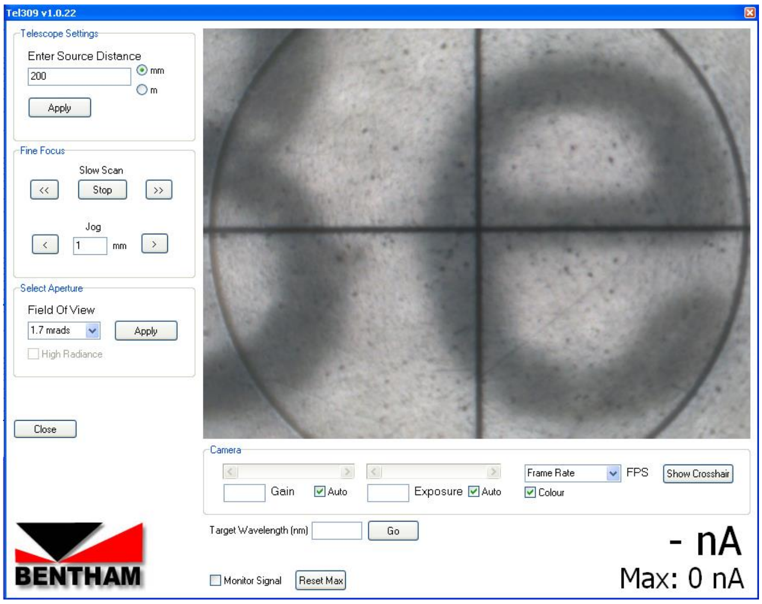

Figure 17: It is a good idea for users to use a business card to focus on at the exit of the SRS12

11mrad calibration

- In the TEL309 Utility window, select 11mrad
- At 200mm the view of the camera of the TEL309/310 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 Utility 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, we 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

4.2.4 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

4.2.5 Source Measurements

- Go to Utilities → TEL309 Utility
- In the TEL309 Utility 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

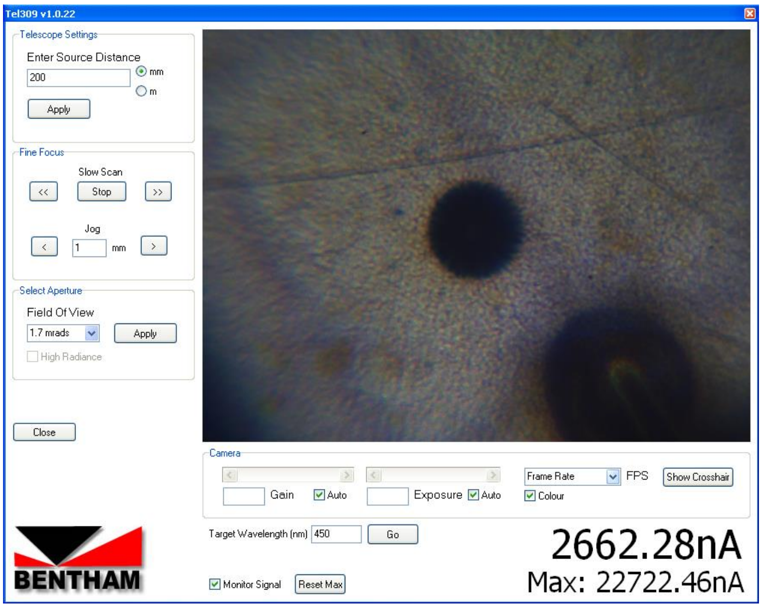

Figure 18: View from TEL309/310 using the 1.7mrad aperture selected. Checking the Monitor Signal Checkbox allows the Tel 309 Utility to measure the current signal from the IDR300

- Position source to get it into focus on the TEL309/310 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!
- It may be useful to place a business card or alignment aid at the CPHA to aid in positioning the source

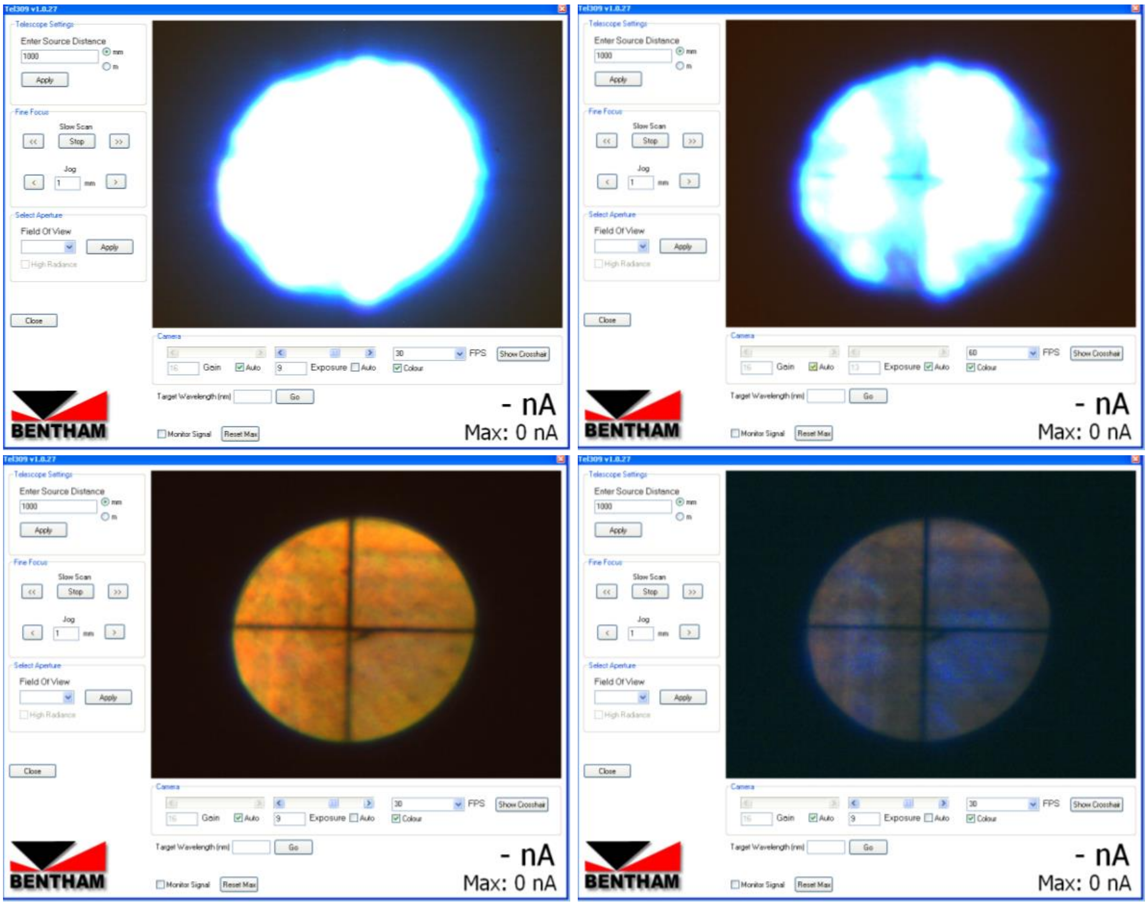

Figure 19: The pictures above show the saturation of the CMOS being reduced with the focus being on the exit pupil and the edge of the LED chip in the background (out of focus)

- 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

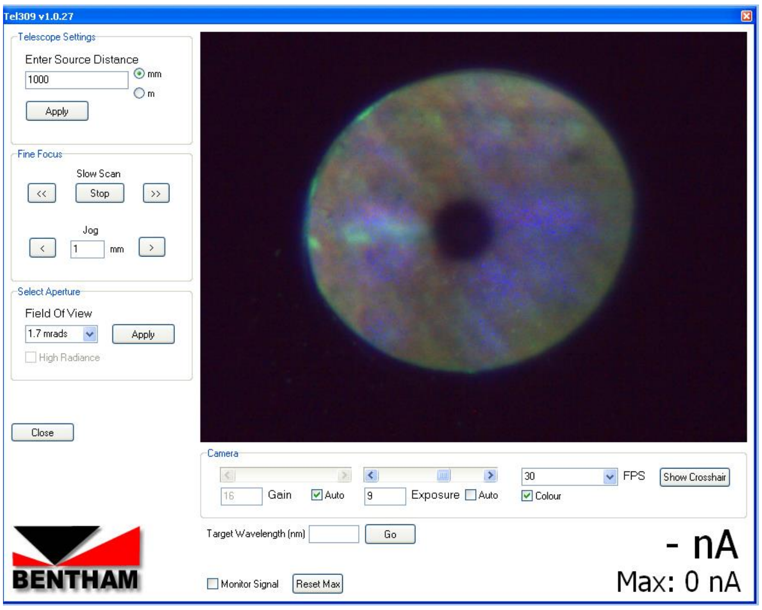

Figure 20: Visual cues can help guide the user in the alignment of the source

- 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 TEL309/310, the 7mm aperture can be placed in the TEL309/310 lens to reduce signal ***(ensure this is removed prior to measurement otherwise an incorrect measurement will result)***

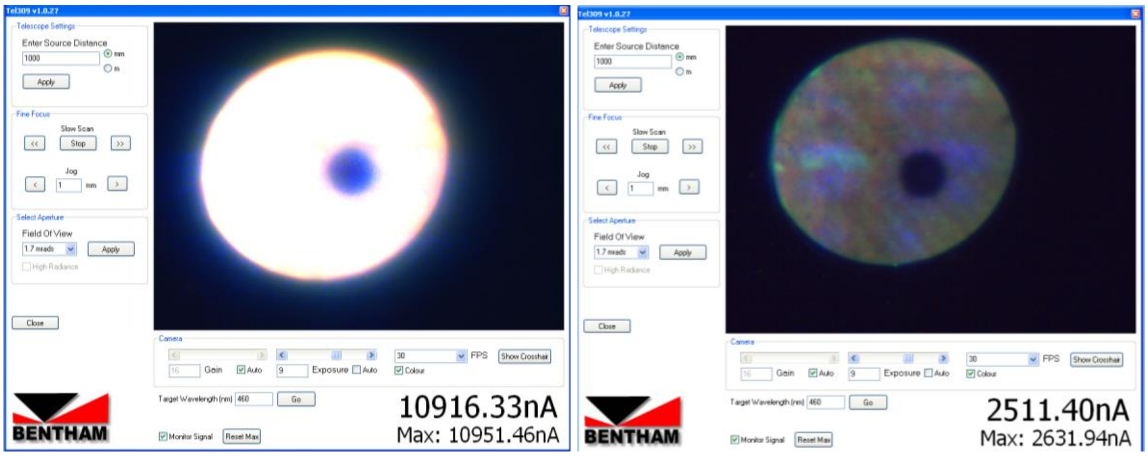

Figure 21: Saturated CMOS in the TEL309/310 (left) and the desaturated image using the 7mm aperture (right)

- 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 utility 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

4.2.6 Overload Conditions

Should the user find that the measurement results in an overload condition, then they can proceed using the following procedure:

- Calibrate the system as normal
- Measure the lamp as normal up until the system overloads and note the wavelength that it overloads at. This will be the absolute spectrum and will provide the correct values that a relative scan can then be attached to
- Insert the 7mm aperture
- Scan the lamp again. This will be the relative spectrum where the shape will be correct but the values will not be and will therefore need to be stitched to an absolute scan
- Use the Spectra Utility in BenWin+ to stitch these spectra together

4.3 Infrared (Relative) Measurements

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.

4.3.1 Hardware Setup

- IDR300-PSL with PbS detector AC electronics
- Relay optic and chopper
- CL6 calibration lamp with 610 supply

Figure 22: Relay optic and chopper used for IR measurements

4.3.2 Software Setup

- Initialise BenWin+ in the infrared configuration

4.3.3 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

4.3.4 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

4.3.5 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.