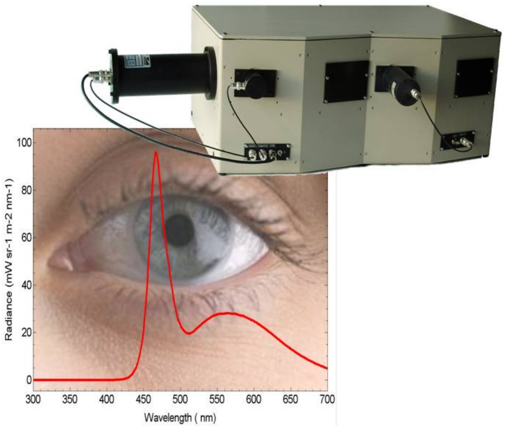
The Light Measurement Company

Bentham IDR300- PSL

Evaluation of the Photobiological Safety of Lamps

User Manual



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1. Introduction

The IDR300-PSL system has been designed to respond to the instrumentation requirements of IEC62471/ EN62471 in the evaluation of the photobiological safety of lamps and luminaires.

The system is based on the IDR300, double, 600mm focal length, monochromator in the Czerny Turner configuration, used to accurately determine the source spectrum.

This integrated spectroradiometer is also furnished with motorised entrance and exit slits and integrated DC detection electronics.

To perform measurements in the infra red, a separate ensemble of AC detection electronics is provided.

In this instance, the IDR300 has been configured for use over the spectral range 200-3000nm.

A range of input optics and accessories have been provided to permit the measurement of spectral irradiance and spectral radiance.

In the DC mode, the system operates over the spectral range 200-1700nm with the PMT, Silicon and InGaAs detectors; in the AC mode, the range is 1000-3000nm with the PbS detector.

This document has been written as an aid in the use of the system and the control software, Benwin+.

Sections 2 to 5 discuss the system component hardware, 6 the software and in sections 7-10 is provided measurement information.

A precautionary note is provided in section 11.

In the appendices are to be found background information deemed to be of interest.

2. Monochromator0

2.1 Introduction

The term monochrome and its variants come to us from the Greek words *mono* "single" and *chroma* "colour".

No light source is truly monochromatic; no light source emits light of a single wavelength, all sources containing contributions from a finite range of wavelengths, termed its spectrum.

It is often of interest to decompose a source into its component wavelengths, for the purpose of determining the spectral distribution (UV, visible, infrared etc), or to employ that source as a means of testing samples under "monochromatic" stimulation.

In either case, a means of wavelength dispersion is required.

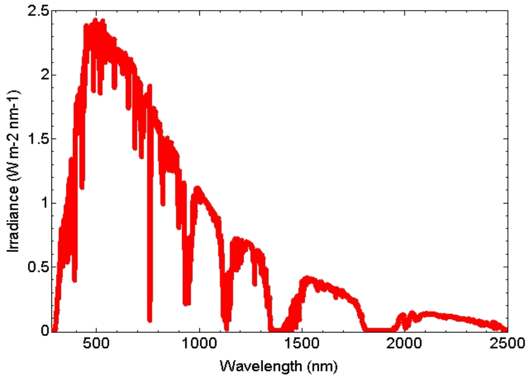


Figure 2.1:- Solar spectrum- from ultra violet to infrared

2.2 Light dispersion

The image of the dispersion of light can be little better conjured up than that of a rainbow.

Though not an entire description of the processes in play, the apparently "white" light from the sun, on travelling through the droplet is refracted, or bent from its path. The amount light is refracted depends upon its wavelength; blue light on one extreme of the visible spectrum is refracted more than the rest of the visible spectrum, through to red light on the other extreme, resulting in a rainbow.

In effect the sun contains wavelength components from the UV to the infra red (heat radiation), not visible to the human eye, but nevertheless part of the solar spectrum.

2.3 Light Dispersion Mechanisms

In terms of scientific instrumentation for use in the laboratory or field, the following are the principal manners of either determining the spectrum of a source.

Mechanism	***Dispersion Process***	***Pros***	***Cons***
Prism	Refraction	-Simple -Inexpensive	-Prism material absorbs light -Non-linear dispersion
Reflection diffraction grating	Diffraction	-Can be optimised	-Linear dispersion -Complex process -Delicate optics -Expensive -Delicate optics
Transmission diffraction grating	Diffraction	-Relatively simple	-Linear dispersion -Complex process -Delicate optics -Expensive -Grating material absorbs light
Band Pass Filter	Band pass filters	-Simple -Relatively inexpensive (in visible-NIR only)	-Low spectral resolution -Low throughput

Of the above techniques, only the reflection diffraction grating can be used over wide spectral range in a practical application, providing potentially very high spectral resolution. It is this technique that is employed in all Bentham monochromators. Henceforth shall be presented the theory and operation of such a device.

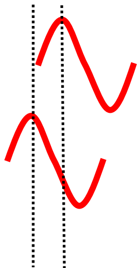
2.4 Wave Interference

Light can be considered as having a wave-like nature. When two such waves are brought into proximity, they interact, the resultant wave depending on the amplitudes, frequencies and relative phases of the two waves. In the context of diffraction gratings, it is sufficient to consider the case of the superposition of two waves of equal frequency (and therefore wavelength). The resultant wave is simply the sum of the two.

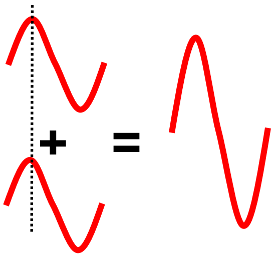
With a phase difference of zero or a whole number of wavelengths, constructive interference obtains, ie $m\lambda$ where m is an integer.

With a phase difference of half a wavelength, they interfere destructively, ie mλ/2 where m is an whole number

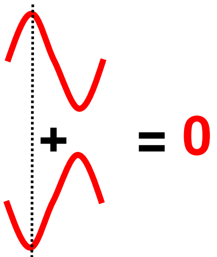
Between these two conditions varying degrees of interference result.



Phase difference



Constructive Interference

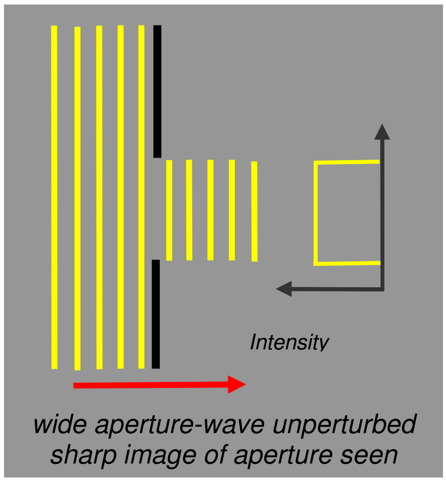


Destructive Interference

Figure 2.2:-Wave interference

2.5 Theory of diffraction
Diffraction describes a variety of processes which obtain when waves, such as light, approaches an obstacle of dimension of the order of their wavelength, and is characterised by the apparent bending of the waves around the object, such as is demonstrated across.

What is transmitted in the one case is a sharp image of the aperture, and in the other a diffracted image of the aperture (seen , whereby most of the light is transmitted on axis, but at wider angles, because of interference effects, a diffraction pattern obtains.



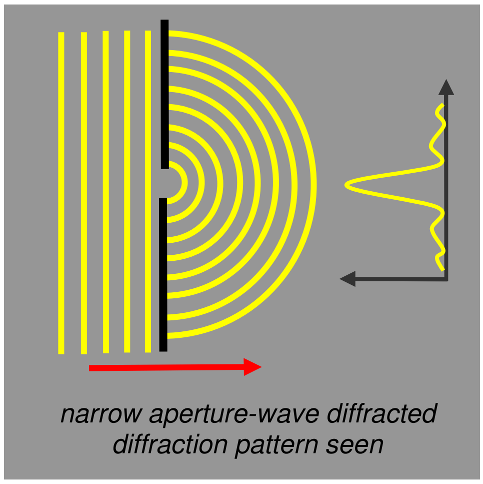


Figure 2.3:-Single slit diffraction

Whilst this example demonstrates the principle in transmission, the same applies were the aperture replaced by a reflecting surface; would be reflected in the case of a narrow mirror light would be reflected in all directions. Note that in the case of reflection, specular reflection obtains, where the peak in intensity is transmitted in the same angle as the angle of incidence.

This is termed single slit diffraction.

2.6 Reflection Diffraction Grating
A reflection diffraction grating is a surface which, on the microscopic scale, is made up of a large number of rectangular grooves of width comparable to the wavelength of light to be considered. Bentham uses gratings with a “groove density” from 75- 2400 grooves per millimetre.

On shining light upon this surface, diffraction at each of the grooves obtains; each groove acting as a (coherent) source of light, emitting a cylindrical wave.

The coherence of these cylindrical waves is an important aspect since any phase difference between adjacent grooves is due solely to geometry and not from the source.

It is the interference of the light from these numerous sources that is of interest.

Diffraction can be visualised by the following, whereby light of wavelength λ is incident at an angle α to the normal of a diffraction grating of groove spacing, d. Light is diffracted along angles β_m into a number, m, of diffraction orders.

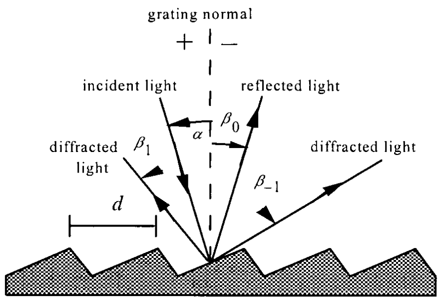


Figure 2.4:- Plane reflection grating diffraction

It is the interference between the waves diffracted from each groove the provides wavelength discrimination as a function of angle.

A sign convention exists for the definition of angles and orders. In general angles are measured from the grating normal to the incident wavefront. Should diffraction occur on the opposite side of the grating normal, then negative angles are used.

This view can be simplified to the following, where one can consider two adjacent grooves separated by a distance, d.

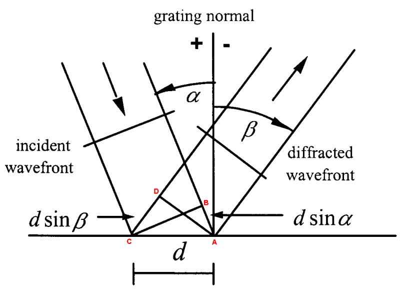


Figure 2.5:- Path difference between neighbouring rays

The geometrical path difference, Δ, between the path of the incident wavefront between A and B and the diffracted wavefront between C and D is

Δ = AB + CD = d sin α + d sin β.....2.1

Now, for constructive interference to obtain, adjacent rays must differ by integer number of wavelengths. This leads to the grating equation.

$$m\lambda = d(\sin\alpha + \sin\beta) \quad ....2.2$$

or

$$Gm\lambda = \sin\alpha + \sin\beta \quad ....2.3$$

where G is the groove density, G= 1/d.

For a given incidence angle α, there shall therefore be a set of discrete angles for which constructive interference shall be observed. At all other angles, there will be some measure of destructive interference.

Here m is the diffraction order and is an integer.

Since the absolute value of the sine function cannot exceed unity, then:-

$$| m\lambda / d | < 2 \quad ....2.4$$

For a particular wavelength the above gives the possible diffraction orders present.

Specular reflection (α =β) always exists, this is the m=0, zero order position, where the grating simply acts as a mirror and the component wavelengths of the incident wavefront are not separated.

In Bentham monochromators, the grating is rotated as a function of wavelength, about a pivot coincident with the central ruling, to scan through wavelengths. The direction of the incident and diffracted light remains therefore unchanged.

In this case, one refers to the angular deviation, 2K, between the incidence and diffraction directions, defined as:-

2K = a – β = constant……..2.4

Further defined is the scan angle, φ, measured from grating normal to the dissector of the beams

$$2\varphi = a + \beta \quad \text{.................}2.5$$

Now, substituting, the grating equation becomes:-

$$m\lambda = 2d\cos K\sin\varphi \quad \text{.......}2.6$$

For a given monochromator K is a constant, therefore one can determine select a wavelength by determining the required grating angle.

2.7 Diffraction orders

As noted above, the grating equation may be satisfied at a given angle by a number of wavelengths of different diffraction orders.

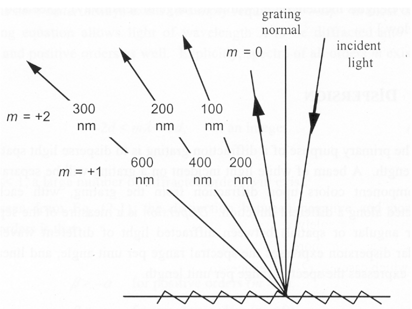


Figure 2.6:- Existence of diffraction orders

This can lead to problems when attempting to measure light in a given diffraction order, when the detection system is capable of sensing the wavelength in the next diffraction order etc.

Order sorting is therefore required, and consists of the filtering of the monochromator input with long pass filters where higher diffraction orders might be present.

This also leads to on explanation for measurement in first order. The wavelength of light that diffracts along the direction of λ_1 in order m+1, is $\lambda_1+\Delta\lambda$, where

$$\lambda_1 + \Delta\lambda = \frac{m+1}{m}\lambda_1 \quad \text{............}2.7$$

Hence we define the free spectral range, the range of wavelengths over which overlapping of adjacent orders does not occur,

$$F_\lambda = \Delta\lambda = \frac{\lambda_1}{m} \quad \text{............}2.8$$

2.8 Diffraction grating production

Gratings found in monochromators are replicas based on master gratings.

Master diffraction gratings are produced by one of two means:-

- Holographic exposure then chemical etch of grooves
- Mechanical ruling of grooves

In the holographic technique a substrate is covered with a photoresist material whose properties change under light stimulation. Exposure to an interference pattern defines the grating outlay, chemical etching is then employed to selectively etch the substrate as a function of the photoresist.

This method produces almost sinusoidal grooves, but of very high surface quality.

The mechanical technique involves the mechanical inscribing, using a diamond tip in a "ruling engine" to define grooves on a metal substrate, a lengthy and difficult process.

This method yields very good, triangular grooves, resulting in gratings of very high efficiency. However, surface defects may have an impact in certain cases by introducing stray light into the monochromator.

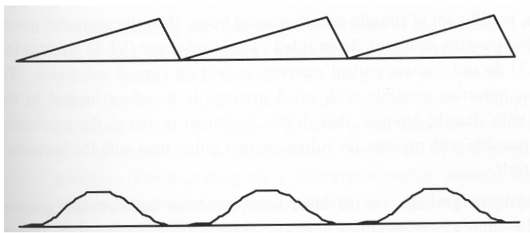


Figure 2.7:- Groove shape obtained using ruling (upper) and holographic techniques

Replica gratings are resin casting of master gratings, on a glass substrate, which are then coated by a suitable metallic coating for the spectral range of use, such as aluminium.

Diffraction gratings may be produced on flat (plane) or non-flat (for example concave) substrates.

2.9 Diffraction grating efficiency

The efficiency of a grating is defined as the power of monochromatic light diffracted into a given order relative to that light incident.

In order to increase the efficiency of a grating at a given wavelength, the angle of the grooves is designed such that the specular reflection from the grating surface lies in the same direction as that wavelength in question.

This procedure is called blazing, the peak wavelength being the blaze wavelength.

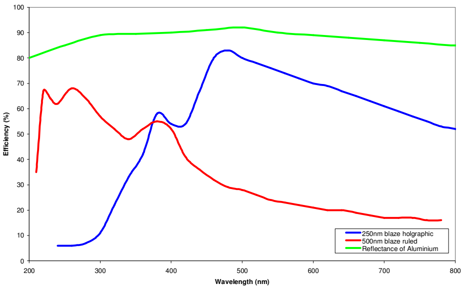


Figure 2.9:- Example grating efficiency curves

The consideration of grating efficiency becomes more complicated when one considers polarised incident light, and in particular the case of TM polarised light in which case the electric field vector is perpendicular to the grooves, giving rise to anomalies, or abrupt changes in the grating efficiency curve.

2.10 Czerny-Turner Monochromator

The Czerny-Turner configuration, as employed in Bentham monochromators, uses a plane diffraction grating.

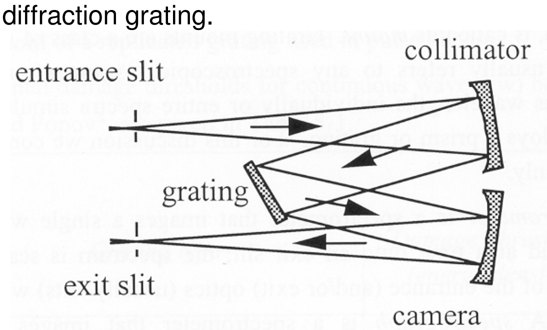


Figure 2.8:- Czerny-Turner configuration

In order to control the location of diffracted light, the grating should be illuminated by collimated light.

Incident light, diverging from an entrance slit is collimated by a first concave mirror. After diffraction from the grating, light is focussed to an exit slit by a second concave mirror.

As a function of wavelength therefore, the grating is rotated to scan through a spectral range.

2.11 Stepping motor drives

It has been seen that in fixed angle monochromators, it is of question to move the diffraction grating through a range of angles in a repeatable manner. To this end, stepping motors are employed.

A stepper motor is a type of electric motor that moves in increments, or steps, rather than turning smoothly as a conventional motor does. The size of the increment is measured in degrees and can vary depending on the application. Typical increments are 0.9 or 1.8 degrees, with 400 or 200 increments thus representing a full circle. The speed of the motor is determined by the time delay between each incremental movement.

Inside the device, sets of coils produce magnetic fields that interact with the fields of permanent magnets. The coils are switched on and off in a specific sequence to cause the motor shaft to turn through the desired angle. The motor can operate in either direction.

When a current is passed through the coils of a stepper motor, the rotor shaft turns to a certain position and then stays there unless or until different coils are energized. Unlike a conventional motor, the stepper motor resists external torque applied to the shaft once the shaft has come to rest with current applied. This resistance is called holding torque.

Stepping motors, combined with gear systems or sine-bar mechanisms are used to provide high precision and highly repeatable monochromators.

2.12 Double monochromators

When using a single monochromator such as that shown in figure 2.6, it is possible that light, entering from the entrance slit, be scattered off the walls and structures constituting the monochromator, reach the exit slit. Therefore, at a given wavelength, λ, an artificially high signal is measured.

This is termed stray light and is of concern where low light level measurements are performed where there exists a significant light component at other wavelengths.

Classical examples are measurements of UV sources and high optical density filter transmission.

Consider for example the measurement of a quartz halogen lamp, a lamp often used as calibration standard.

The following figure demonstrates the effect of scattered light in measuring the lamp UV output where there exists a significant amount of visible light.

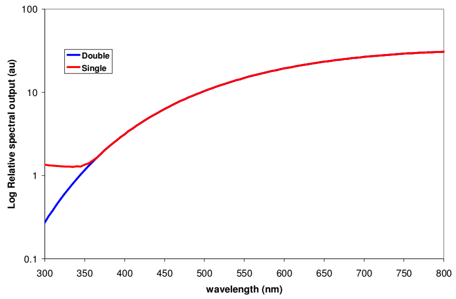


Figure 2.10:- Measurement of QH lamp with single and double monochromators

A double monochromator situates a second single monochromator at the exit of the first.

Entering the first monochromator is all the light from the source to be measured; entering the second monochromator is the wavelength selected and a level of stray light, which one desires to reduce.

In the second monochromator, the desired wavelength re-selected; at the exit slit one finds that the level of the stray light has reduced to the square of the case of the single, for example a factor 10^3 down in a single, a factor 10^6 down in a double.

There are two possible configurations of double monochromator; with additive or subtractive dispersion.

With additive dispersion, the first monochromator is followed by a device of similar type.

The band of light transmitted from the first to second is further dispersed, resulting in twice the dispersion of a single system; for a given required bandwidth therefore, the monochromator slits may be doubled in size with respect to a single monochromator, which increases the system throughput.

With subtractive dispersion, the second monochromator is operated in an inverse manner to the first in such a manner that at the exit slit there exists no net dispersion.

At the exit of the first monochromator, the light to be transmitted to the second monochromator is dispersed across the slit; at the exit of the second monochromator this dispersion does not exist and all the wavelengths are combined.

The dispersion of a subtractive double monochromator therefore is the same as that of a single monochromator.

The subtractive configuration is often employed in such systems as primary transfer standard where the uncertainty of dispersion across the detector slit is unacceptable (yet for most applications of no real consequence).

A further important point is that of the slits of the double monochromator.

With additive dispersion, it is the entrance and exit slits which define the system bandwidth, the middle slit between the two monochromators being employed to reduce the stray light being transmitted to the second element. The middle slit should be at least twenty percent larger than the largest slit of the system to prevent tracking problems (beating) between the two component monochromators.

With subtractive dispersion, it is the entrance and middle slits which define the system bandwidth; the exit slit is employed to reduce the system stray light and again should be at least twenty percent larger than the largest slit of the system.

2.13 Wavelength calibration

The TM family of monochromators contain a turret (per monochromator) upon which can be mounted up to three diffraction gratings.

The turret is driven through a reduction gear from a stepping motor which is used in the micro-stepping mode, yielding an angular resolution of 0.00072° per step which corresponds to 500,000 steps per revolution of the turret

Each monochromator includes a two-stage encoder which allows the unit to be sent to a fixed point (negative limit) which is used as a datum. On software initialisation, the turret is sent to this "park" position.

For each grating, is provided two parameters; the first is the number of steps which must be made from the datum position to reach the nominal zero order position for that grating (Zord), the second is a scaling factor (value near 1) which gives the best wavelength linearity (alpha).

For systems having multiple exit ports, by use of swing away mirrors (SAMs), setup involves ensuring the good calibration of all ports with one set of grating parameters.

The results of the wavelength calibration (zord and alpha per grating) is provided for all monochromator exit slits.

By far the most useful wavelength calibration source is the mercury lamp, the spectrum of which contains a large number of discrete emission lines in the UV- visible domain, the wavelength of which never change.

It is worthy to note that in the case of high pressure mercury lamps, the lines may be broadened with respect to those emitted from a lower pressure lamp.

Values are given in appendix 1.

In spectroradiometry, the first order contribution is most commonly used, however, for purposes of wavelength calibration, higher order contributions may be of use.

Furthermore, in the case of gratings for use in the infra red, where there exists no useful contribution from the mercury lamp output, the zero- order position is used to set up gratings, in which case light incident on the entrance slit is transmits directly to the exit slit.

In effect the mercury spectrum is virtually omnipresent to a certain extent in the laboratory environment, overhead fluorescent tubes containing some of this vapour.

Alternative calibration sources are lasers or interference filters of known transmission, which may be suitable for certain wavelength regions, but do not have such wavelength coverage as the mercury lamp.

Please see appendix 1 for information concerning checking the wavelength calibration.

2.14 IDR300 Monochromator

The monochromator of this system is an IDR300 with motorised slits and integrated DC detection electronics (see §5.2.2).

Figure 2.11:- IDR300 monochromator

This IDR300 composed of two 300mm focal length monochromators, with additive dispersion, to yield a 600mm focal length double.

In each single monochromator, up to three diffraction gratings are mounted on a turret to permit use over a wide spectral range.

The turret is driven through a reduction gear from a stepping motor which is used in the micro-stepping mode, yielding an angular resolution of 0.00072° per step which corresponds to 500,000 steps per revolution of the turret.

For each grating is provided two parameters, the first is the number of steps which must be made from the datum position to reach the nominal zero order position for that grating (zord), the second is a scaling factor (value near 1) which gives the best wavelength linearity (alpha).

Each monochromator includes a two-stage encoder which allows the unit to be sent to a fixed point (negative limit) which is used as a datum. On software initialisation, the turret is sent to this position.

A swing away mirror (SAM) is situated at the exit slit of the first monochromator permitting therefore the choice between using a 300mm single monochromator or a 600mm double.

A further swing away mirror is situated at the exit of the second monochromator permitting the use of two detectors at this exit.

There exists one entrance slit and three exit slit: one on the output of the single monochromator, and two on the output of the double.

All control and detection electronics (see §3) being internal to the monochromator, power is supplied directly to the unit; the monochromator is also directly connected to the controlling USB bus.

A six position filter wheel is to be found on the inside of the monochromator entrance port. These filters are used to suppress transmission of higher diffraction orders.

2.15 Diffraction gratings

The turret of monochromator one is fitted with one of each of the following gratings; the turret of monochromator two does not have the 400 line grating since measurements in the infra red are not performed with the double, but single configuration.

Line density (g/mm)	λ Blaze (nm)	Maximum λ range (nm)
2400 Holographic	250	200-600
1200 Ruled	500	300-1100
400 Ruled	1600	1000-3000

Table 2.1: Diffraction gratings installed

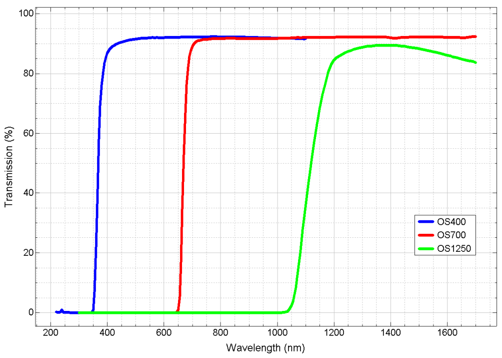
2.16 Order sorting filter wheel

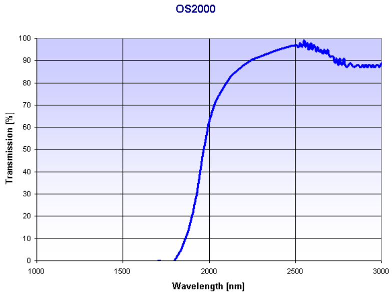
As explained in §2.4, the governing diffraction equation admits solutions for integer multiples of the wavelength in consideration, thus diffraction orders. Most spectroradiometry is performed on the first order contribution, it is necessary to avoid measurement of higher order signals for correct measurements.

An order sorting filter wheel is to be found on the inside of the monochromator exit port. The installed filters are described in table 2.2.

Position	Filter	Insertion (nm)
1	Open	0
2	OS400	400
3	OS700	700
4	OS1250	1250
5	OS2000	2000
6	Shutter	-

Table 2.2: Filter wheel content





Figures 2.12 & 13:-Typical OS filter transmission

A blank disk, in position six stops light from entering the monochromator during dark current and offset measurements.

2.17 Monochromator Bandwidth

The monochromator bandwidth, defined in nm, is the range of wavelengths seen by the detector at one time, and is directly linked to the monochromator slits in use.

This is an important quantity to take into account, particularly when measuring sources have fine spectral features such as line emission- for example the measurement of a source having two spectral lines one nanometre apart with a system bandwidth of five nanometres, will result in the measurement of a single line. In many instances this is of no concern, since the power measured shall nevertheless be correct.

The effect of monochromator entrance and exit slits on monochromator bandwidth can be viewed in two manners.

In the first instance, the monochromator is an imaging system; the input port is imaged at the exit port; the dimension of the monochromator entrance slit defines the image size at the exit port.

Furthermore, at the exit of the monochromator, since the light incident thereupon is dispersed, one can imagine the wavelength axis running along parallel to the wall of the exit slit, and the size of this slit determines how many wavelengths can be seen at one time.

One can imagine therefore an infinite number of images of the entrance slit, of incrementally differing wavelength, presented parallel to the exit slit; whichever of the two are the largest, defines the bandwidth of the system.

In a double monochromator, a further slit is included, the middle slit (in the case of a system having additive dispersion).

The purpose of this slit is to reduce the amount of stray light going from the first to second monochromators and should at all times be set to at least 20% larger than the largest slit in the system, else tracking problems between the component monochromators shall result.

The slit function of a monochromator provides interesting information with regards the device performance and the system bandwidth.

The slit function may be determined by the measurement of a source of narrow spectral width, such as a laser.

One should perform a measurement at smaller steps than the system bandwidth (for example 0.1nm), over a spectral range of around four times the expected bandwidth, centred on the expected wavelength of the emission line, for example 632.8nm for the HeNe laser.

The full width half maximum (FWHM) of this spectrum provides the bandwidth of the system.

Inspecting the signal at one bandwidth, two bandwidths etc. relative to the peak, provides information of the stray light performance of the system.

If the entrance and exit slits are of the same dimension, the slit function shall have a triangular profile, otherwise, the function shall be flat-topped.

It is worthy to note that care should be made in making this measurement- it is not sufficient to shine a laser in the entrance slit of the monochromator.

This measurement should ideally be performed by filling the entrance slit, for example with the use of an integrating sphere, and illuminating the sphere with the source.

Finally, it follows of course that slit dimension has an impact of the light throughput of the monochromator, and in certain instances where a reduction in signal is required, either the entrance or exit slit is reduced, whilst maintaining the same system bandwidth.

It is preferable that the slit to be reduced be the exit slit to avoid any conflict with the input optic.

The slits of IDR300 are motorised, and are all set to the same dimension. For slit control please see §6.5.6.

For information, the following table shows the bandwidth obtained for the monochromator and gratings of this system with a range of slit widths, for the single and double configurations.

It is important to remember that to perform a scan with a step size lower than the bandwidth obtained is satisfactory, on the contrary to step larger than the bandwidth results effectively in the loss of information.

Grating Groove Density (l/mm)		**2400**	**1200**	**400**
Reciprocal Dispersion (nm/mm)		1.35	2.70	8.11
Slit widths (mm)	**Part no. for pair of slits**	**Bandwidth produced (nm)**		
0.05	FS (0.05)	0.07	0.14	0.41
0.1	FS (0.10)	0.14	0.27	0.81
0.2	FS (0.20)	0.27	0.54	1.62
0.37	FS (0.37)	0.50	1.00	3.00
0.4	FS (0.40)	0.54	1.08	3.24
0.5	FS (0.50)	0.68	1.35	4.05
0.56	FS (0.56)	0.76	1.51	4.54
0.74	FS (0.74)	1.00	2.00	6.00
1	FS (1.00)	1.35	2.70	8.11
1.12	FS (1.12)	1.51	3.03	9.08
1.48	FS (1.48)	2.00	4.00	12.00
1.85	FS (1.85)	2.50	5.00	15.00
2	FS (2.00)	2.70	5.40	16.21
2.78	FS (2.78)	3.76	7.51	22.53
3.7	FS (3.70)	5.00	10.00	29.99
4	FS (4.00)	5.40	10.81	32.42
5.56	FS (5.56)	7.51	15.02	45.07
8	FS (8.00)	10.81	21.62	64.85

Table 2.3: Single configuration bandwidth

Grating Groove Density (l/mm)		**2400**	**1200**
Reciprocal Dispersion (nm/mm)		0.68	1.35
Slit widths (mm)	**Part no. for pair of slits**	**Bandwidth produced (nm)**	
0.05	FS (0.05)	0.03	0.07
0.1	FS (0.10)	0.07	0.14
0.2	FS (0.20)	0.14	0.27
0.37	FS (0.37)	0.25	0.50
0.4	FS (0.40)	0.27	0.54
0.5	FS (0.50)	0.34	0.68
0.56	FS (0.56)	0.38	0.76
0.74	FS (0.74)	0.50	1.00
1	FS (1.00)	0.68	1.35
1.12	FS (1.12)	0.76	1.51
1.48	FS (1.48)	1.00	2.00
1.85	FS (1.85)	1.25	2.50
2	FS (2.00)	1.35	2.70
2.78	FS (2.78)	1.88	3.76
3.7	FS (3.70)	2.50	5.00
4	FS (4.00)	2.70	5.40
5.56	FS (5.56)	3.76	7.51
8	FS (8.00)	5.40	10.81

Table 2.4: Double configuration bandwidth

2.18 Setting mains voltage

The IDR300 is fitted with a switch mode power supply. Fuses are fitted dependant on location. Fuses are:-

110 V- 1260mA anti- surge
220/240V – 630mA anti- surge

3.Input Optics

3.1 Spectral Irradiance
3.1.1 Introduction

Spectral irradiance is defined as the incident radiant power, Φ issued from a source at a given distance, over surface area A, as a function of wavelength.
Hence

$$E(\lambda) = \frac{\Phi(\lambda))}{A} \text{ ....3.1}$$

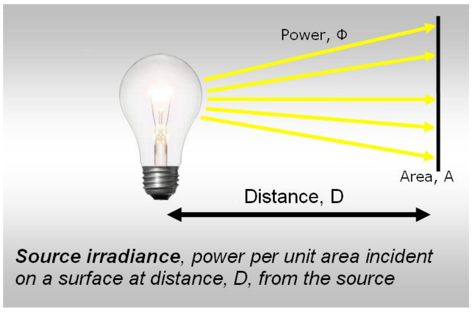


Figure 3.1:- Definition of irradiance

In the measurement of irradiance it is important to take account of contributions from angles in the entire hemisphere above the input optic.

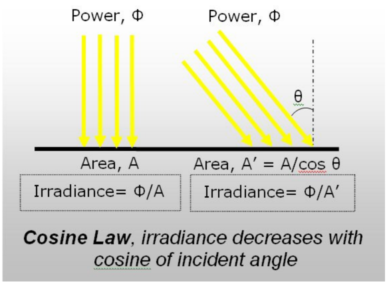


Figure 3.2:- Measurement over entire hemisphere

From the above, one obtains the angular component as a function of the orthogonal component,

$E = E_{normal} \cos\theta$……………….....................3.2

This is called the cosine law. The input optic should therefore weight the incident radiation as a function of the cosine of the angle of the incident light.

Furthermore, one should take into account the distance between source and input optic. Irradiance is inversely proportional to distance, therefore it is necessary to reference all measurements to the measurement distance used.

The units of spectral irradiance is $W.m^{-2}$ nm^{-1}, which when integrated over suitable limits yields the irradiance of the source at a given distance in $W.m^{-2}$.

3.1.2 Measurement Distance

It is important to note the spectral irradiance is dependant of distance. Where a specific application does not define the measurement distance, it is recommended to perform measurements at a distance five times the largest dimension of the source, and no less than 200mm.

A bare source, one without lenses nor reflectors, may be considered as a point source; the irradiance reduces with the inverse of the distance from the source squared, the inverse square law.

The inverse square law states that the product of irradiance and measurement distance squared is a constant, $E_1 r_1^2 = E_2 r_2^2$.

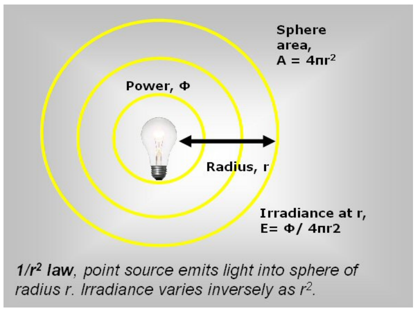


Figure 3.3:- Inverse square law

Cosine response, f_2

The directional response of a diffuser is characterised by f_2, a measure of the deviation from a true cosine response.

$$f_2 = \int_0^{\frac{85 * \pi}{180°}} f_2^* \sin 2\theta d\theta \text{ ....3.3}$$

$$\text{where } f_2^* = \left| \frac{S(\theta)}{S(0)\cos(\theta)} - 1 \right|$$

θ is the angle from the perpendicular to the diffuser
S(θ) measured signal at angle θ
S(0) measured signal one axis of diffuser

3.1.3 D7 cosine diffuser

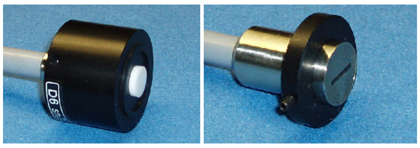
This system has as input optic the Bentham D7 cosine response diffuser, and two metre randomised quartz fibre bundle to transport light to the monochromator entrance slit.

The cosine response of this diffuser has been calibrated, and is less than 1% f2 error.

Please see corresponding calibration certificate.

On the diffuser side, the fibre bundle is pushed fully into the diffuser body and held in place by a grub screw on the side of the diffuser.

On the monochromator side, the fibre bundle has a slit-shaped output. This is adapted to the entrance slit by an adapting piece of metalwork, and held in place by a thumb screw.



Figures 3.4 & 5:- Attachment of fibre to D7_H and bundle adaptor to entrance slit

The fibre bundle is fragile; it is necessary to handle with caution, relax any mechanical stress, and to ensure that the fibre bend radius is never less than 100mm.

The D7 diffuser is recommended for use over the spectral range 200-1100nm where its' f_2 error is less than 1%.

Beyond 1100nm, its' cosine response degrades.

It should be noted that the thickness of the diffusing element is greater than that of the D6; should signal level problems be experienced for example in the UV, it is recommended to perform measurements in that domain with the latter diffuser.

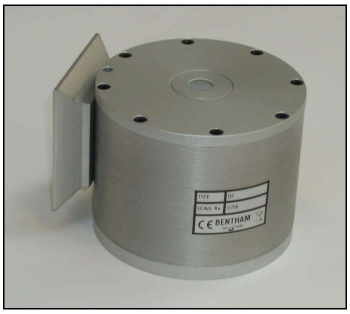
Please see corresponding calibration certificate for the response of this device.

The D7 has a grub screw port to attach it securely to the fibre bundle.

3.1.4 D8 Integrating sphere

To cover the spectral range beyond the 1100nm limit of use of the cosine diffusers, there is provided the D8 integrating sphere based cosine response input optic.

This device may be coupled to the monochromator either via the FOP-UV or via a relay optic for IR operation.



Figures 3.6:- D8 input optic

The cosine response of the integrating sphere-based input optic is never as good as that of the diffuser, and as such, the D7-H should be used in the first instance below 1100nm.

The D8 interior is made of a PTFE- type plastic, a good diffuse reflector over the spectral range required.

Should the D8 be used with the FOP-UV, it should be noted that an adaptor has been provided to match the diameter of the FOP-UV to the aperture in the sphere.

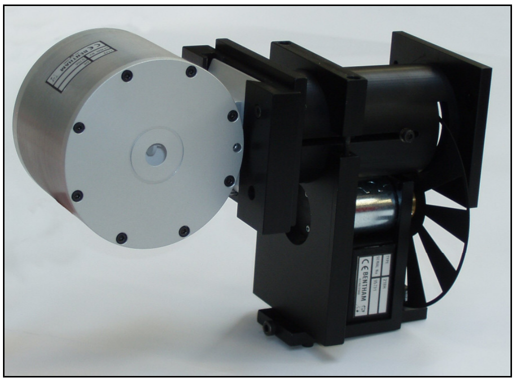
A practical issue in measuring in the IR is encountered in this configuration, since the quartz bundle has a significant OH^- absorption feature around 1400nm, which eliminates most of the signal.

Alternatively, the D8 can be mounted to the entrance slit or the relay optic by use of the quick change adaptor; the dovetail to the side of the D8 is placed as far as the lower stop on the adaptor, and the two side M4 grub screws clamp the device in place.

3.1.5 Relay Optic

When operating the system in the AC regime, it is necessary to interrupt the input beam with an optical chopper, the 218, to produce an AC probe signal.

A relay optic is provided, to which is mounted the optical chopper and the D8 input optic as seen below.



Figures 3.7:- Relay optic with D8 fitted

The relay optic is mounted such that the groove for the chopper is closest to the monochromator exit slit.

The optical chopper is provided with an adaptor for attachment around the metalwork of the relay optic, the chopping blade fitted, passes without interference through a slot in the barrel.

The D8 adaptor can be coupled to the relay optic via nuts & bolts.

The relay optic comprises two CaF_2 lenses, to image the output of the D8 onto the entrance slit of the monochromator.

3.1.6 Fibre Bundle

Light is coupled from the diffuser to the monochromator by a randomised quartz fibre bundle.

This bundle is formed as a round ferrule on the diffuser side, and one the monochromator side, a rectangle to better adapt to the shape of the entrance slit.

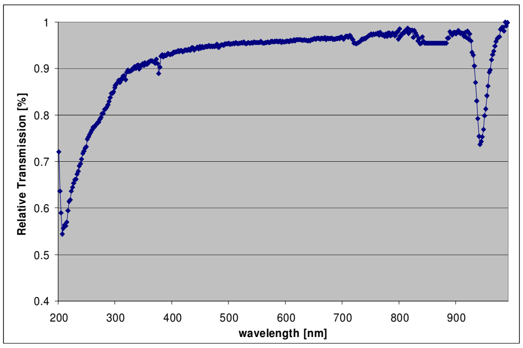


Figure 3.8:- Relative transmission of quartz fibre bundle

On the diffuser side, the fibre bundle is pushed fully into the diffuser body and held in place by a grub screw on the side of the diffuser.

On the monochromator side, the fibre bundle has a slit-shaped output. This is adapted to the entrance slit by an adapting piece of metalwork, and held in place by a thumb screw.

The fibre bundle is fragile; it is necessary to handle with caution, relax any mechanical stress, and to ensure that the fibre bend radius is never less than 100mm.

3.2 Spectral Radiance

3.2.1 Introduction

Spectral radiance is defined as power, Φ per unit area, A, emitted by a source into unit solid angle, Ω, in direction ,ε, to normal.

$$L(\lambda) = \frac{\Phi(\lambda))}{A.\Omega.\cos\varepsilon} \quad \text{...........................3.4}$$

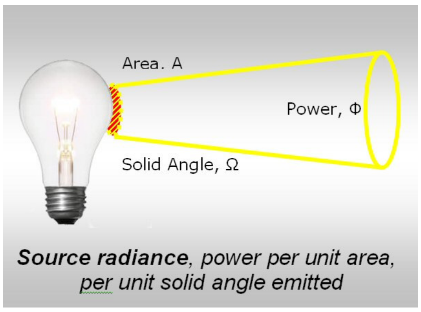


Figure 3.9:- Spectral radiance

The units of spectral radiance is W. sr^{-1} m^{-2} nm^{-1}, which when integrated over suitable limits yields the radiance of the source in W.sr^{-1} m^{-2}.

Solid angle is defined as the angle subtended by area, A, on surface of sphere of diameter, r; Ω= A/r2, units steradian (sr). A sphere corresponds to 4π sr.

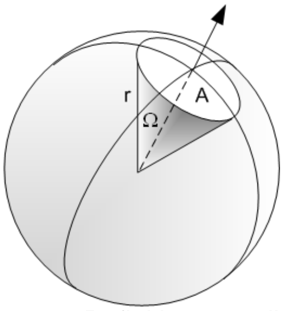


Figure 3.10:- Definition on solid angle

Radiance is a useful quantity since it provides information of how an optical system (such as the human eye) will view a sourced due to the solid angle term; the size of the entrance pupil of an optical system defines the solid angle of measurement.

Radiance is independent of distance since as the observation point moves away, the increasing area of the source viewed is negated by the reduction in the solid angle of measurement.

Irradiance provides information of the power per unit area arriving at the pupil of the eye, but not how much of this is transmitted to the retina; radiance on the other hand is conserved, so one can determine retinal irradiance via source radiance and knowledge of the geometry of the eye.

In terms of the photobiological safety of lamps, the source radiance is used to determine retinal irradiance in hazard calculations.

In traditional spectroradiometry, when measuring radiance, the area sampled should be smaller than the extent of the source and consideration of the uniformity of the area sampled should be made. On the contrary, here concerned with retinal irradiation, what is measured is a physiological radiance in given fields of view.

3.2.2 Measurement Techniques

The measurement of spectral radiance involves the isolating of a portion of the source (area), defined by a field of view, and measuring in a given solid angle.

Provided that the source fills the field of view, and that the source be uniform, spectral radiance is independent of measurement distance; for a given field of view, as the measurement distance changes, the solid angle of measurement and the area measured correspondingly negate the effect of the other.

There are two principle manners of measuring spectral radiance, one based on an imaging technique, the other on the measurement of spectral irradiance, using apertures to stop down the source to define a field of view.

In the case of lens or reflector based sources, this latter technique is not applicable since the placement of an aperture at the source acts merely as a field stop, reducing the signal, and not an aperture stop, reducing the radiation footprint of the source.

Imaging technique
The standard method involves using an optical system to image the source onto the detection system, the dimension of the detector (and the lens- image plane distance) defining the measurement field of view.

This technique is the easiest to perform, particularly in the case of narrow fields of view where by the alternative method very small aperture stops would be required.

Furthermore, care should be taken with regards the entrance aperture to the imaging system, which defines the solid angle of measurement.

A non-uniform source may present a non-uniform profile thereupon, compared, for example, to a uniform calibration source, which may lead to incorrect results.

In the case of the photobiological safety of lamps a 7mm aperture is a possible approach to counter this effect.

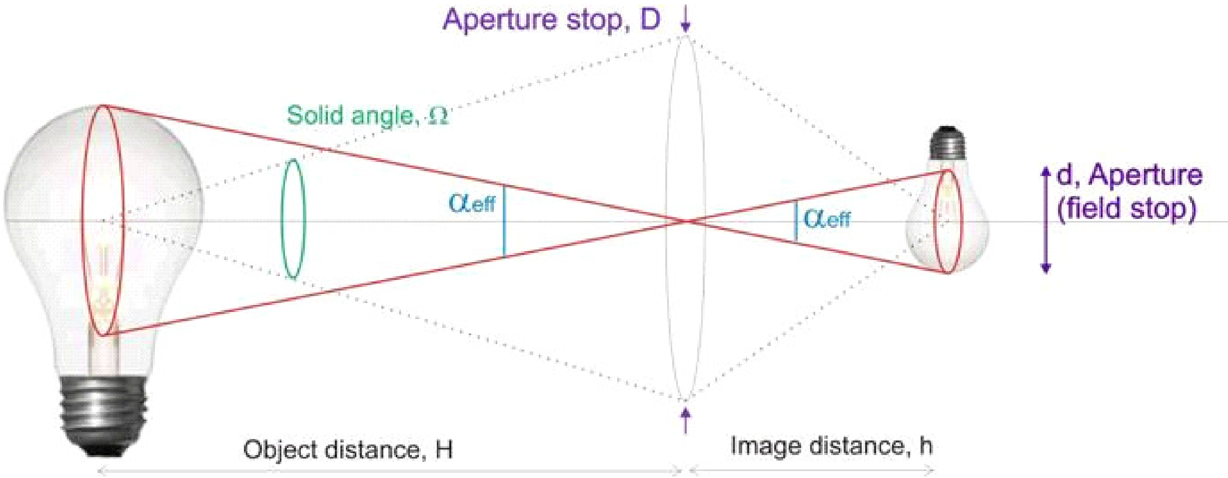


Figure 3.11:- Measurement of radiance- imaging

Measurement of Radiance as Irradiance
This measurement can also be performed as one of irradiance in a defined field of view, and the dividing the irradiance results by the solid angle corresponding to the field of view.

It is recommended that where possible, the imaging technique be employed.

Exceptionally, however, of the measurements required by the photobiological safety of lamps standard, very large fields of view are required, which would be difficult to achieve with an imaging telescope; recourse is therefore taken to the radiance as an irradiance technique (100mrad field of view).

3.2.3 Measurement Conditions

The golden rule of measurements of spectral radiance, is that the area measured be smaller than the source, else an average radiance of the source and the dark background for example would be measured.

For standard measurements of radiance therefore, the aperture selected to define the view should under-fill the source, ie the view of the aperture should be smaller than the source.

One should also pay attention to the fact that the source may not be uniform, and that using a over-sized aperture would lead to results that on average would be lower than the smaller aperture.

Exceptionally, in terms of the photobiological safety of lamps, the field of view has a biophysical importance, related to the image of the source on the eye, and the spread of this image on the retina as a function of eye and body movement.

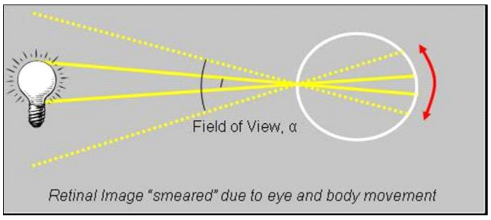


Figure 3.12:- Retinal image averaging

The field of view employed may be larger than the source in question to yield an average radiance.

3.2.4 TEL309 telescope

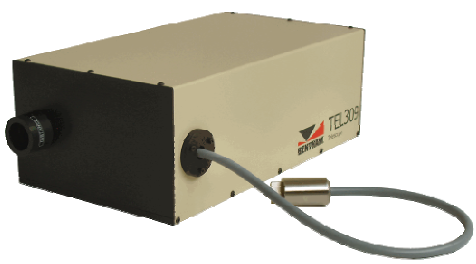


Figure 3.13: TEL309

From figure 3.11, it should be noted that as the measurement distance changes, so does the image distance. Now, the field of view is approximately equal to the ratio of the aperture diameter to the image distance.

It follows that as one continuously changes the measurement distance, one requires a continuously variable aperture to obtain the required fields of view of 11 and1.7mrad.

This is effectively achieved in the TEL309 with the following features

-Measurement distance 200mm to 50m
-Close and distance lenses
-Motorised periscope to change image distance
-Motorised aperture wheel containing two circles of apertures, sixty-four in total
-CCD camera viewer
-Computer controlled via Benwin+ (see §6.5.11)

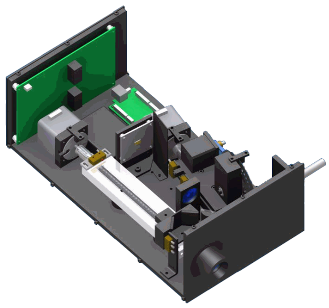


Figure 3.14:- TEL309 optics

A 7mm stop is provided as aperture stop at the lens.

The TEL309 is coupled to the IDR300 via a short quartz fibre bundle (FRAGILE). This fibre is deliberately short to reduce the OH-absorption at 1380nm to permit measurements to 1400nm of radiance.

4. Calibration standards

4.1 Introduction

This system comprises three calibration standards, a CL6-H quartz halogen standard of spectral irradiance, a CL7 deuterium standard of spectral irradiance and a SRS12 quartz halogen based standard of spectral radiance .

4.2 UV Irradiance
4.2.1 CL7 spectral irradiance standard

The Bentham CL7 is an enclosed Deuterium-lamp based spectral irradiance standard, calibrated at a distance of 5.5mm with respect to the front of the housing.

A DAR (diffuser adaptor ring) is provided for use with the Bentham family of cosine diffusers. This ensures that the diffuser is held at the calibration distance in use.

This calibration is traceable to NPL, and is calibrated against the NPL_{2003} scale.

A purge port is provided on the side of the deuterium lamp should this be required.

Figure 4.5: CL7 Deuterium lamp and supply

This standard uses a 30W deuterium lamp.

4.2.2 Deuterium Lamp

The deuterium lamp, with a high UV output and little VIS/ NIR, is the preferred source for UV measurements, in terms of signal level and of scattered light.

The lamp discharge is initiated using a heated cathode, made of a tungsten filament, typically coated with a highly emissive material. The 705 power supply applies a heater current for around one minute prior to establishing the arc.

The envelope of these lamps is cylindrical in shape.
There exists a number of variants having a “snout” in the output direction to reduce discoloration of the output window by condensation of arc vapours.

Furthermore, when used for long periods, lamps of natural fused silica show a loss of output due the effect of UV, resulting in a loss in transmission. This effect is a result of impurities in the material and is known as solarisation.

A window of a solarisation insensitive material is usually employed at the lamp output.

An example is synthetic fused silica, a high purity material, to obviate the effects of solarisation.

The lamp is filled with low pressure, very high purity deuterium gas. Deuterium is the selected gas rather than hydrogen due its more intense UV continuum.

Lamp life is estimated at around 500hrs use.

4.2.3 705 Deuterium supply

The 705, on switch on, provides the Deuterium lamp with a controlled application of heater current prior to establishing the arc.

The sequence is as follows:-

•0-65s => 0.9A dc heater current
•65-90s => 0.8A dc heater current
•> 90s => 0.6A dc heater current
•Anode current 300mA

There are three electrical connections between the 705 and the CL7, anode (red), cathode (black) and heater (blue).

On switch on the 705, a red LED illuminates; after one minute the discharge is commenced and a green LED illuminates.

Should the restart sequence be started, indicated by a amber LED, firstly ensure that the electrical connections are properly fitted.

4.2.4 Lamp use

The CL7 lamp has been calibrated at a distance of 5.5mm from the front face of the housing, and is usually used with a Bentham diffuser and DAR adaptor.

A warm-up time, with the diffuser in place of at least 20 minutes is recommended prior to calibration.

4.2.5 Operation Notes

For correct lamp operation, and to preserve the validity of calibration, please respect the following:-

•Ensure the correct electrical connections are respected at all times
•Do not remove bulb from housing nor adjust rear screws

•Do not touch bulb with bare fingers
•Bentham recommend that the device should be re-calibrated every 100hrs use or 1-year, whichever comes first
•The lamp requires approximately ten minutes warm-up time.

4.3 UV-Vis-IR Irradiance
4.3.1 CL6 spectral irradiance standard

The Bentham CL6_H is an enclosed spectral irradiance standard, using a 150W quartz halogen lamp.

Figure 4.1: CL6_H

The CL6_H has been calibrated in the horizontal position and should be used in this manner.

The Bentham D7_H and D8 cosine input optics are adapted to the CL6 via adapter rings which sets the front of the optic to the calibration distance; 5.5mm in the case of the D7-H and 22mm in the case of the D8.

This calibration is traceable to NPL, and is calibrated against the NPL_{2003} scale.

This lamp should be operated at 6.300A, using the Bentham 605 constant current supply, ensuring that the fan is connected.

It is recommended to apply a warm-up time of ten to fifteen minutes.

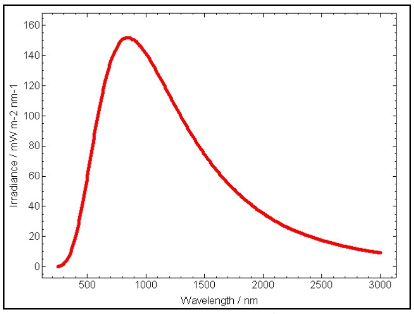


Figure 4.2:- Typical CL6 output

4.3.2 The quartz halogen lamp

Tungsten is a very reliable example of filament material, such as in those bulbs that are traditionally used in domestic situations.

These latter are on the whole very unreliable and have a relatively short lifetime- for spectroradiometric applications, a source of stable amplitude and spectral output is required.

This instability is due to discolouration of the bulb envelope during lifetime and filament failure.

During lamp use, an incandescent lamp filament reaches very high temperatures, around 3000K at which some of the tungsten evaporates and moves around inside the bulb by convection currents.

If the envelope is cold, it is likely that the tungsten is deposited thereupon, leading to the gradual discolouration of the glass.

Furthermore, since the tungsten is evaporated, gradually the structure is of the filament is thinned in places. This leads to a runaway failure. The resistivity of the thinned section increases, leading to increase in power dissipation and temperature at that point, and consequently higher rate of evaporation. Theses factors conspire to thin the filament further until such point that the filament breaks, or “bridges”.

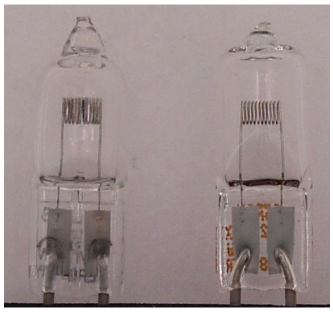


Figure 4.3:- Used (left) and new QH lamps, note filament degradation

These problems are mitigated by using the quartz halogen lamp.

A quartz halogen lamp has two main differences with respect to “standard” incandescent lamps, which together promote the halogen cycle.

Firstly, the bulb is filled with a halogen gas which combines with the evaporated tungsten from the filament.

Provided that the envelope of the bulb is over 250℃, the tungsten-halogen compound does not condense thereupon, and eventually returns via convection to the filament, at which point the tungsten is re-incorporated, releasing the halogen to continue the process. This constitutes the halogen cycle.

In order to maintain the envelope at high temperature the envelope is made as close to the filament as possible without melting. Quartz, which can withstand higher temperatures than conventional glass, is therefore used as the envelope material.

The re-deposition of the tungsten is of course a random phenomenon, eventually parts of the filament structure become thinner and failure ensues.

Bulb temperature being therefore important, for the halogen cycle to work, the lamp must be run for long enough to heat up the lamp. The lamp should not be under-run either-under-running the lamp less than 80% of rated voltage will result in failure of the halogen cycle due to the lower bulb temperature.

In some instances the orientation of the lamp becomes important, for example in some instances the envelope is not equidistant above/ below the filament.

Running such a lamp in the pins down orientation is satisfactory since the upper part remains hot, but in the pins down orientation, it is possible that it becomes sufficiently cool to condense tungsten.

Should a lamp be under-run, it is possible to re-evaporate that material condensed on the envelope by letting the lamp run to the temperature required to re-initiate the halogen cycle.

It was evoked previously that tungsten filament emission is close to that of a black body. However all tungsten filament lamps are housed in an envelope to prevent oxidation of the filament. The transmission of the envelope can modify the output of the filament.

Quartz for example transmits 250-3000nm and is used in most cases, however where for example UV blocking is required, a hardened glass may be used which transmits from 380nm. The quartz halogen lamp is typically used in the spectral range 250-3000nm.

This lamp is run from the Bentham 608 power supply.

It is important to run this lamp at its specified current to ensure that the halogen cycle functions, ensuring long lamp life.

These lamps are slightly under-run with respect to their nominal operating conditions.

A trade-off is established between under-running to increase lamp life time, whilst maintaining the halogen cycle.

4.4 Spectral Radiance
4.4.1 SRS12 Radiance Standard

The Bentham SRS12 consists of a baffled 100W quartz halogen lamp mounted in a 12" diameter Ba_2SO_4- coated integrating sphere.

The output port of the device is 100mm diameter, for which a dust cover has been provided to prevent contamination of the reflective surface of the sphere.

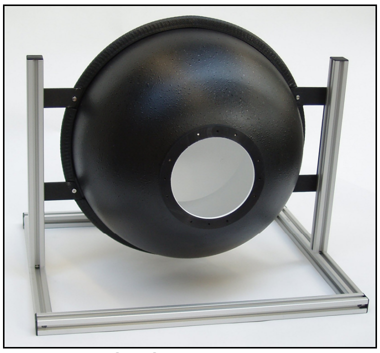


Figure 4.6: SRS12 radiance standard

The SRS12 has been calibrated, traceable to NPL.

This lamp should be operated at 8.500A, using the Bentham 608 constant current supply (see next section).

It is recommended to apply a warm-up time of ten minutes.

4.5 605 constant current supply

4.5.1. Introduction

The Bentham 605 is a constant current power supply designed for use with stabilised light sources and calibration standard sources.

Max output current= 12A dc
Max output power = 250W
Max compliance voltage= 35V dc

A key switch permits selection of three pres-set and ne variable current setting.

A fan port is provided for those lamps requiring cooling.

4.5.2 Specification

Temperature stability	30 ppm/℃
Indications	Green LED= Power on Red LED = Lamp failure
Front panel meter	Output voltage indicator (accuracy +- 0.1V not suitable for precision voltage readings)
Fan output	110V ac (typically 200mA)
Mains input voltage:-	Back panel switch to select nominal 110V or 220/240-CV ac
Mains frequency	50 or 60 Hz
Mains input fuse	Anti surge (220/240V)

4.5.3 Setting mains voltage

Whilst the mains voltage is set up at Bentham according to where the device is sent, it is of good practice to verify before powering up the 608.

A toggle selector should be found underneath the mains connector to the rear of the 608.

Please ensure that the voltage of the country in which the 608 is to be used is displayed.

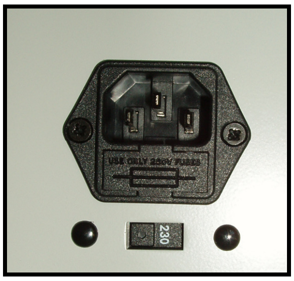


Figure 4.4: mains voltage selector

At Bentham, the appropriate fuse (plus a supplement) is fitted. Should the voltage setting be wrong, please ensure that the correct fuse is installed.

4.5.4. Lamp Operation

•Connect bias leads and ensure fan is connected where required
•Ensure key switch points to correct desired current
•Power up 605
•The operating conditions of the various lamps of this system are as follows:-
•Power off 605 to extinguish lamp
•It is recommended to not move the lamp for the first few minutes after power off to prevent damage to the filament

Source	Current (A)	Nominal Voltage (V)	Fan
CL6-H	6.3000	24	Y
SRS12	8.5000	12	N

•To prolong lamp life, ensure lamp polarity respected. and that those housings requiring a fan have the fan connected into the 605 lower right socket.
•Depress the on/off switch to illuminate/ extinguish lamp.

4.5.5 Operation Notes

For correct lamp operation (and in the case of calibrated sources, to preserve the validity of calibration), please respect the following:-

All sources:-

•Ensure the correct polarity is respected at all times, connecting red to red and black to black from lamp to 605.

•Do not touch bulb with bare fingers.

•Do not run the lamp at a current lower than that at which it is specified

•The lamp should be operated in configuration in which calibrated ie. pins up/ pins down. Operation in any other sense may invalidate calibration and curtail lamp life.

•In general bare lamps require around a 5 minute warm up time, housed lamp up to 15 minutes for optimal stability

•It is of use to note the voltage displayed on the 605 LCD. This is for indication only, but can be used to determine lamp condition[1]. These lamps are operated at slightly under their nominal rating, and as such the voltage readings may be lower than nominal voltage

•Bentham recommend that calibrated sources be re-calibrated every 100hrs use or 1-year, whichever comes first.

[1] One of the failure mechanisms of such lamps is "bridging" or short-circuit of part of the filament, leading to a correspondingly lower voltage and reduced light output.

5. Detector & Detection Electronics

5.1 Detectors

5.1.1 Introduction

Whilst there are three monochromator exit ports, this system is supplied with four detectors as follows:-

5.1.2 Photomultiplier

The DH3, multi-alkali photomultiplier tube (PMT) is used over the range 200 to ~850nm.

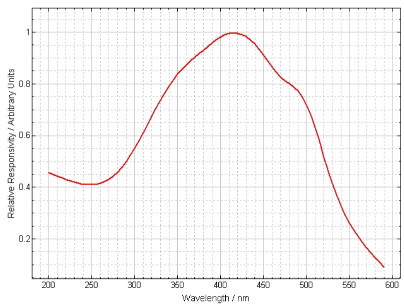
This PMT comprises a photocathode front window, held at negative set high voltage, and a chain of ten dynodes, dropping an equal voltage between each up to the anode at 0V.

Having a low work function, incident light liberates electrons from the photocathode which are accelerated toward the first dynode. Electrons colliding with the first dynode generate secondary electrons, this process continues along the dynode chain up to the anode.

The high voltage required for the electron multiplication process is derived from the an HV supply situated in the MDE electronics. This has been factory set to 750V.

Never expose the PMT to ambient light whilst the HV is ON.
This includes when changing slits or diffraction gratings.

A typical spectral responsivity curve follows:-



Figures 5.1:-Multii-alkali PMT typical relative responsivity

The multi-alkali PMT is a very sensitive, and reasonably stable device with a dark current around five hundred pico-amperes.

The PMT attaches to the exit slit via an adaptor plate; the adaptor plate is attached to the exit slit via 4 M3x16 screws, and the PMT attaches to this plate via M4 screws. One should ensure that the rubber o-ring provided is correctly installed between the adaptor and the monochromator and between the PMT and the adaptor plate.

There are two electrical connections to the PMT; the thicker cable with a plastic insert in the BNC connector is used for the HV, the standard BNC cable, for the signal channel, connected to Input 1 of the IDR300.

The PMT is mounted on the exit of the double opposite the entrance slit.

It is recommended to truncate the use of this device to around 820nm, beyond which the device quickly loses response and may demonstrate unstable behaviour.

5.1.3 Silicon detector

The silicon photodiode is responsive over the spectral range 200-1100nm.

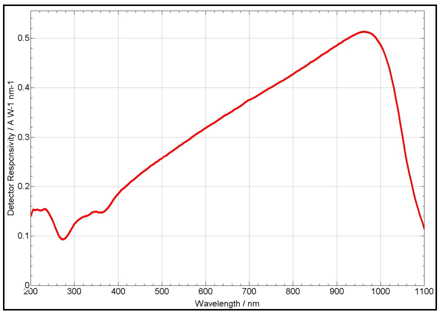


Figure 5.2:- Silicon detector typical responsivity

The active area of this device is 10x10mm.

Whereas the PMT provides high electron gain, the silicon detector provides on average less than one electron per photon incident thereupon, resulting in a substantially less sensitive device. This explains the significant reduction in signal from the PMT to silicon detector.

This detector is mounted on the perpendicular second monochromator output slit.
This device is used as a bridge between PMT and InGaAs, but can also be used in the stead of the PMT in cases of very high signal which would otherwise saturate the PMT.

It should be noted that in the region 1050-1100nm, at the band edge of the device, the responsivity may be particularly sensitive to changes in device temperature brought about by changes in ambient temperature.

It may, in such cases be desirable to switch to the InGaAs device.

This device should be connected to input 2 of the IDR300.

5.1.4 InGaAs detector

The Indium Gallium Arsenide detector is responsive over the range 800-1700nm.

A 3mm diameter device, it is fitted with a lens to de-magnify the output of the exit port to better recover signal.

In a similar manner to the silicon device, the InGaAs device is a photodiode.

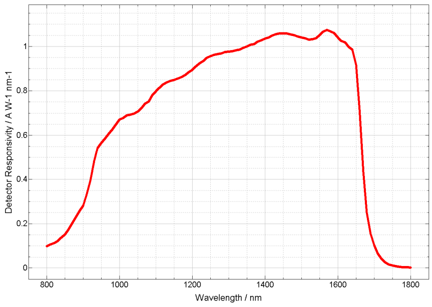


Figure 5.3: Typical InGaAs responsivity

This device is mounted to the exit port of the first monochromator, and should be connected to amplifier input 3 of the IDR300.

5.1.5 PbS-TE detector

The above detectors cover the spectral range 200-1700nm, via DC electronics.

In the infra red region, one must have recourse to AC electronics.

In this regime, the input signal is chopped at a given frequency, and the detector response, at the same frequency is recovered using a lock-in amplifier.

The infra red wavelengths at which these devices are responsive are also those heat wavelengths that are emitted by the monochromator, background etc.- chopping the source avoids such background from giving a measureable signal.

The PbS device is Peltier cooled for stability. This cooling current is derived from the CPS1M controller, with connections via the 5-pin amphenol. The cooling current has been set in factory to 0.5A at 23°C. As the ambient temperature decreases/ increases, the cooling current, as displayed on the CPS1M shall be modified.

Furthermore, the PbS detector is operated in the photoconductive mode; as light is incident on the device, it changes the effective device conduc.

Applying a voltage across the device, in a voltage divider, provides a measurable response.

The voltage supplied is the high voltage used for the PMT, factory set to 750V.

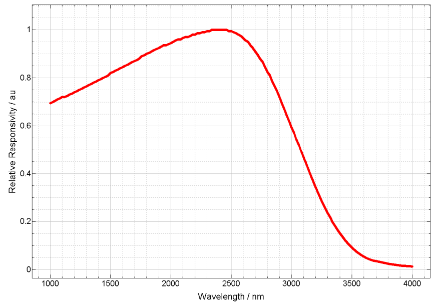


Figure 5.4:- Relative response of PbS detector

The cooling is provided by the CPS1M, located in the 417 electronics bin. Electrical connection is via amphenol (5-pin) socket to the connector to the rear of the detector.

At room temperature, the cooling current has been set to 0.5A.Should the ambient temperature rise, the current shall rise correspondingly.

This cooling current corresponds to a device temperature of around -10℃.

The high voltage is derived from the Bentham 215 high voltage supply.

The high voltage is taken from the same port as for the PMT, connected by the thicker BNC cable; the signal via the standard BNC cable should be connected to input 1 of the 477 pre-amplifier.

5.2 Detection electronics

5.2.1 Components

This system comprises two sets of detection electronics.

The DC electronics are housed underneath the monochromator of the IDR300; the AC electronics are housed in a separate box, the 417.

The various components are as follows.

5.2.2 DC electronics

5.2.2.1 DC Current Amplifier/ Integrating ADC

The 487 is used as the main amplifier in dc systems employing photodiode or photomultiplier detectors. At low frequencies such devices give their best performance when connected to this type of virtual ground input.

The input effectively has zero input impedance and hence no voltage is generated across the device as a result of the photocurrent.

This short circuit operation enhances linearity of detectors and reduces the effect of cable capacitance.

The output of the current amplifier goes directly to the ADC. The output of the current amplifier is 0-10V per range.

There exists effectively two such amplifiers in this system, number one containing inputs one and two; number two, input three.

5.2.2.2 ADC

The ADC uses a continuously running voltage to frequency converter to produce a pulse train whose frequency is proportional to the instantaneous input voltage. The pulses are accumulated in a counter.

At fixed intervals, 100ms, the contents of the counter is transferred to an output buffer and the counter reset to zero. The total number of pulses accumulated by the counter in any counting period represents the true average of the signal during that counting period.

If the accumulated pulses from a number of counting periods are added and normalised then a true average over a longer period is obtained.

The ADC has two other special features which enhance its usefulness in light measurements systems.
Firstly, the input to the ADC is offset giving the unit a small negative range. This ensures that negative going noise peaks, occurring in near zero signals, are correctly averaged while retaining most of the available resolution for positive going signals.

Secondly, the ADC provides information to the computer indicating that a transient overload has occurred at some point during the conversion period. This information is essential if accurate measurements are to be made on pulsed light sources such as CRT monitors.

The ADC provides 2000 counts per volt and has a maximum of 20000 counts.

Due to the quantum nature of light and the way in which optical detectors work, signals in light measurement systems are always accompanied by electrical noise. The limit of low light level detection is often imposed by the ability of the measuring system to distinguish between the signal to be measured and the associated electrical noise.

In most cases, where the noise is truly random, the signal to noise ratio can be improved by averaging. For a signal accompanied by random noise the signal to noise ratio will increase in proportion to $1/\sqrt{T}$ where T is the averaging period.

With dc systems the maximum period which can be used for averaging is limited by so called dc drifts (i.e. low frequency noise. The noise power in fact increases continuously as zero Hz is approached).

The ADC therefore behaves as a digital averager with the averaging period programmable in 100ms increments.

For dc systems the averaging period can be fixed for a particular experimental set-up or can be varied depending on the signal level to give a substantially constant signal to noise ratio for all signal levels. Software schemes have been used where the averaging period is determined by looking at the variance between successive readings or, more simply, by linking the averaging period to the sensitivity range of the amplifier so that averaging period increases as the sensitivity required increases.

This last approach is very useful in solar UV measurements where in a typical spectral scan from 280nm to 400nm the signal level changes by ~10^6.

Similarly, measurements which have included a transient noise pulse such as that produced by Cherenkov events in the window of a photomultiplier, can be recognised and repeated if required.

5.2.2.3 High Voltage Supply

The PMT (and PbS) high voltage is derived from the an high voltage supply in the IDR300.

Connection is made to the detectors by thick BNC cable (having a connector with an insert which inhibits connecting to wrong place)

The high voltage is set in factory to the recommended level, 750V.

Use the flick switch to switch on; a green LED indicates HV on.

There exists two HV output, both can be used at the same time.

5.2.3 AC electronics

5.2.3.1 417 module housing

The 417 bin provides power to and houses Bentham detection electronic modules.

The display section of the 417 can be used to display the analogue output of certain installed modules.

A rotary switch permits selection of displayed channel.

Switch Position	Function Displayed
A	Output of 485 (0-10V)

Table 5.1:- Live display channels

A BNC socket provides output of the function selected by the rotary switch.

Whilst the mains voltage is set up at Bentham according to where the device is sent, it is of good practice to verify before powering up the 417.

A toggle selector should be found underneath the mains connector to the rear of the 417. Please ensure that the voltage of the country in which the device is to be used is displayed.

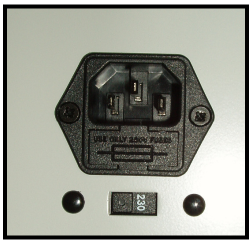


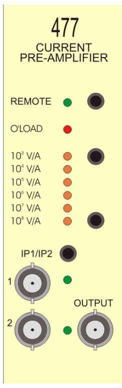
Figure 5.5: Voltage selector displaying voltage in use.

At Bentham, the appropriate fuse (plus a supplement) is fitted. Should the voltage setting be wrong, please ensure that the correct fuse is installed.

The fuse rating is as follows:-

220/240V -630mA anti- surge
110V -1260mA anti- surge

5.2.3.2 477 AC current preamplifier



This programmable current pre-amplifer in normal use is controlled by Benwin+.

It is possible to use locally should the need arise (for example when setting up lock-in amplifier).

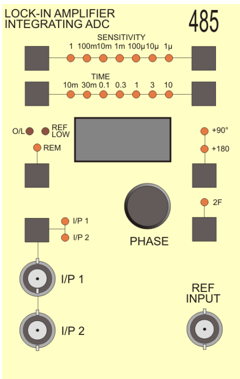
To use locally, push the RTL button. This permits using the two buttons to the right of the gain range LEDs to change current gain range and the lower button to change between inputs.

Overload of range in use is indicated by red LED.

The output of the 477 is 0-10V.

The output of the current amplifier should be connected to input 1 of the 485 module.

5.2.3.3 485 Lock-in amplifier/ ADC



The 485 combines a lock-in amplifier with an analogue to digital converter.

Inputs to the 485, are either directly from a voltage generating detector or via a current amplifier.

Reference input, the output signal from the chopper control module is also required for use.

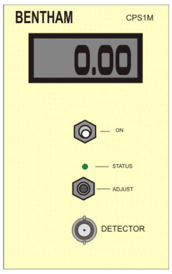
The attributes of the lock-in amplifier vary per detector used. This should be set up before use. Please see section §6.5.8.

The procedure for optimising performance shall follow. To use locally, push the RTL button.

Each gain range of the lock-in amplifier outputs 0-10V.

The ADC component of this device is the same as that of the 487, as described above.

5.2.3.4 CPS1M Peltier Supply



The CPS1M is a feedback Peltier cooler controller, set in factory to a fixed temperature.

At room temperature this is set to 0.5A cooling current. This corresponds to a device temperature of ~-10℃.

The CPS1M is connected to the Peltier cooled device via Amphenol socket.

A flick switch turns cooling on/ off. Cooling is established within thirty seconds.

As a function of ambient temperature, this cooling current may vary.

5.2.3.5 218- Chopper Controller

The optical chopper is controlled by the 218 unit.

The dial shows the chopping frequency for a ten-slot chopper blade. This dial can be locked and unlocked by a small tab underneath the dial.

A 10- slot blade being recommended the viewed frequency is the actual frequency.

It is recommended to operate this system at either 175 or 225Hz.

Connection between the controller and the chopper is by an amphenol socket connector. Ensure that this is not confused with that of the detector cooler.

Furthermore, ensure that a BNC takes the reference output to the reference input of the lock-in.

An optical sensor on the chopper provides feedback to the controller to provide the reference signal. Ensure that the reference from the front of the controller goes to the lock-in amplifier reference input.

6. Benwin+

6.1 Introduction to Benwin+

Benwin+ is a Windows software designed to control Bentham's range of monochromators, detection electronics and accessories.

On running the software, initiating an initialisation procedure establishes communication with the hardware.

Benwin+ then reads a file of type *.cfg, (entitled system.cfg by default). This file describes the elements of hardware to be controlled and their USB address (PID and VID)

By default a *.atr file of the same name as the *.cfg file used is looked for. This file describes the parameters of the instruments of the system.

Groups of cfg, atr files and scan properties can be saved in a configuration to permit easy migration between setups. Configurations are saved in .xml files.

Features include:-

• User initiated or time-delayed spectrum scanning (schedules)
• Easy system calibration, irradiance, radiance, detector responsivity etc
• Obtain spectrally integrated quantities (candelas etc.
• Instantly obtain colorimetric data
• Perform transmission, absorption and reflection measurements
• Perform simple arithmetic functions
•Add-on for control of translation stages, goniometers, data acquisition from other instruments etc
•Direct export of measurement data to excel, with capability of running macros

The software can also be run in stand-alone mode to view measurement results at a later time.

The following sections will be divided into configuration, measurements, analysis and menu reference.

6.2 System configuration

Windows shall recognise all Bentham USB devices, without the requirement for additional drivers, however the USB camera of the TEL309 shall require separate drivers installed.

For all but the TEL309, the process to add new hardware should be followed once for each instrument before using Benwin+.

•Connect the USB to the monochromator and power on
•Wait until windows finds new hardware
•Allow windows to search for the required drivers automatically
•Perform the same process for the 417 detection electronics

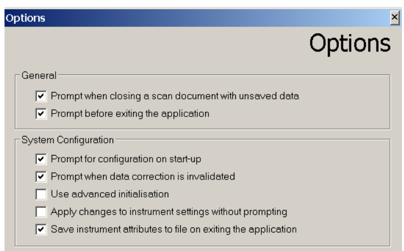
To install the TEL309:-
•Power on and connect USB
•On CD locate TEL309 drivers, run setup.exe
•Proceed through installation

6.3 Installing Benwin+

•Insert Benwin+ CD into computer, and double–click on setup. This takes you through the setup process, select complete installation
•A Bentham/ Benwin+ folder is created in c:/program files (local hard disk)
•A shortcut to Benwin+.exe shall be found also on the desktop

This system operates via a configuration manager to migrate between different measurement setups with facility. This is setup initially by the following operation:-

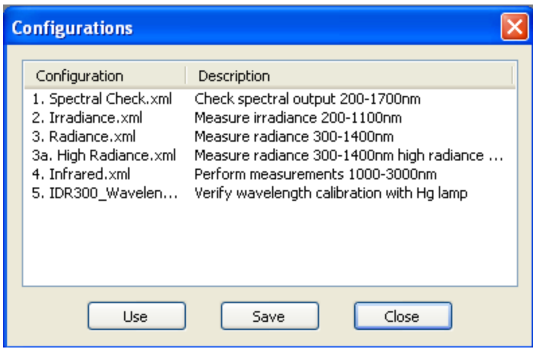
•Run Benwin+
•Go to tools/ options
•Check the item "prompt for configuration on setup"



•Close Benwin+

6.4 Getting the software started

•Run Benwin+.
•You shall now be prompted with the following dialogue box:-



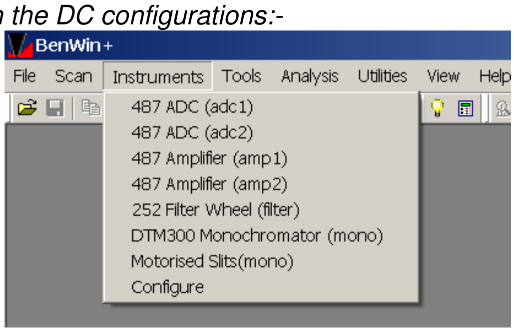
•Double click on the desired configuration
•The system is now ready for use.
•Should it be desired to migrate between configurations, it is recommended to close Benwin+ and select the new configuration on re-start.

6.5 Instrument attributes and configurations

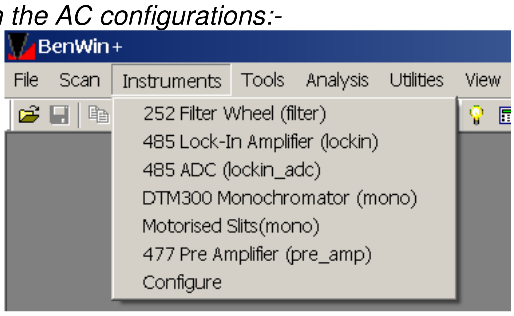
Instruments

The instruments menu lists the system components, giving access to their properties.

In the DC configurations:-



In the AC configurations:-



Note that these properties are saved in the attributes file.

On closing Benwin+, by default any changes made herein are saved. This default can be removed by going to tools/ options and de-selecting “save instrument attributes to file on exiting the application”. Hit apply.

Furthermore, in Instruments/ configure/ advanced>> via a bottom right hand link one can access a link to change the instrument names field should this be required.

6.5.1 Configurations

The attributes, hardware configuration, scan parameters etc. of a given setup are saved in the global configuration. In this system there currently exists three configurations, DC-Irradiance, DC-Radiance (using TEL309) and AC.

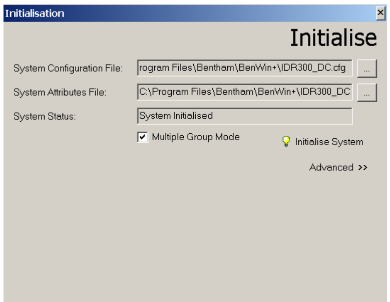
The DC-Irradiance configuration uses only instruments part of the IDR; the DC-radiance includes the TEL309 and AC includes the IDR300 and the 417 AC electronics bin.

For reference these configurations are setup as follows:-

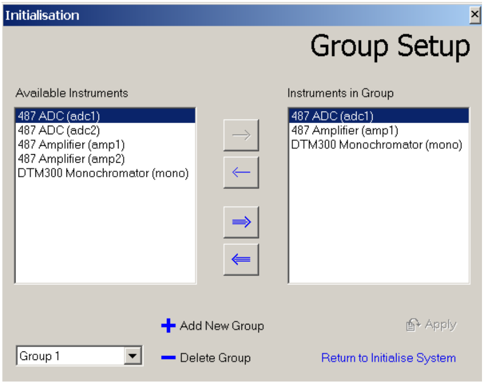
Both DC configurations:-

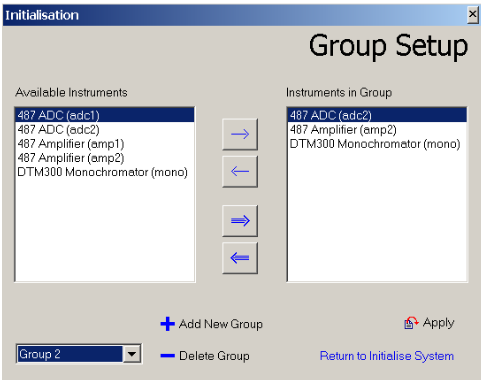
•Uses IDR300_DC.cfg and IDR300_DC.atr
(or IDR300_DC_TEL.cfg and IDR300_DC_TEL.atr)

•In Tools/ advanced initialisation use multi group setup

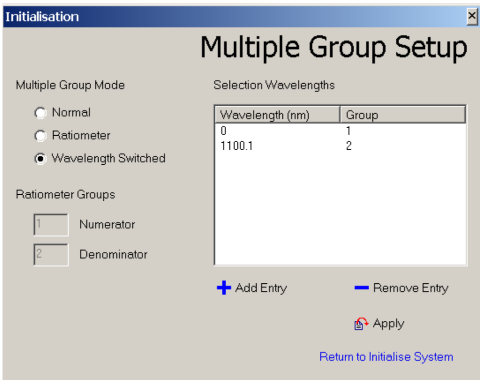


•In advanced, set up instruments are defined two groups as below. One group describes the monochromator and DC electronics 1 the other group the monochromator and DC electronics 2.





•In advanced, multiple group set up, is defined the switching point between the two groups.

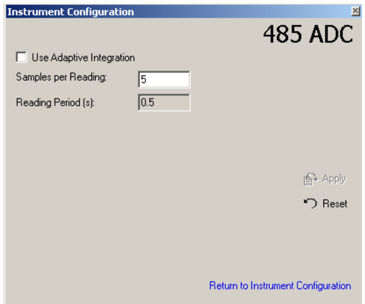


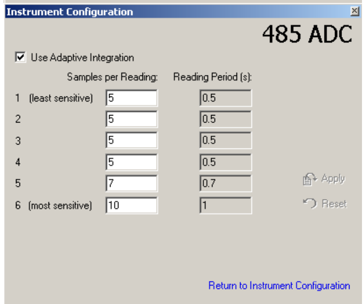
AC:-

•Uses IDR300_AC.cfg and IDR300_AC.atr
•In Tools/ advanced initialisation use simple group setup, multiple group mode is not selected
•In advanced>> setup instruments, only one group is defined with all elements therein group setup Uses IDR300_AC.cfg and IDR300_AC.atr
•In advanced, multiple group set up, the normal mode is selected

6.5.2 Analogue-Digital converter

The ADC of the 485 module integrates over 100ms periods. One can choose how many of these periods shall be taken to determine the reading at each wavelength.



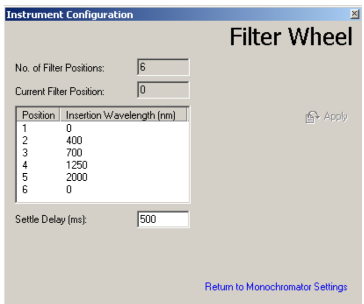


A good number to use for reasonable signal is 5 averages.

One may also select adaptive integration which permits varying the number of averages taken as a function of the gain range of the current amplifier, fewer averages in the low gain ranges and more in the higher gain ranges to smooth out noise.

6.5.3 Filter Wheel

The filter wheel has six positions, populated as standard as described in §2.12. The filter wheel page is as follows.

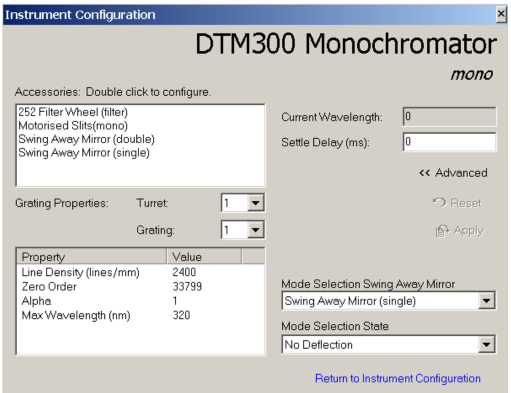


The settle delay is the pause taken by the system following each action. 1000ms is sufficient.

6.5.4 Monochromator

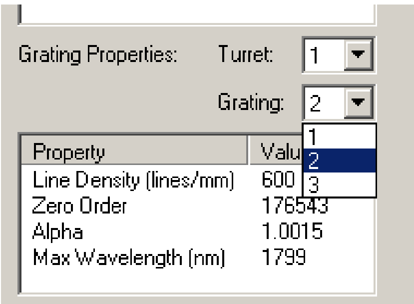
Selecting this page gives access to the parameters of the monochromator.

Selecting Advanced>> gives access to the grating properties: line density, zord, alpha and maximum wavelength.



The pull down arrow permits toggling between gratings.

The zord and alpha measurements are obtained from the calibration certificate.



The max wavelength can be changed to optimise signal, for example where one grating loses efficiency another might gain. One should also take into account the change in bandwidth.

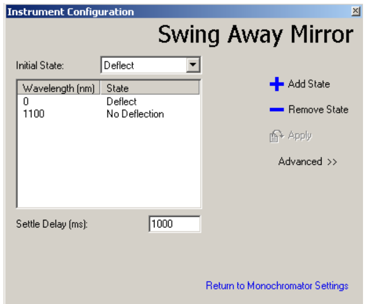
The following maximum ranges should not be exceeded:-

Line density (g/mm)	λ Blaze (nm)	Maximum λ range (nm)
2400 Holographic	250	200-600
1200 Ruled	500	300-1100
400 Ruled	1600	1000-3000

A settle delay of 100ms is sufficient.

6.5.5 Swing Away Mirror (SAM)

Accessed via a link in the monochromator page is the SAM page, named single or double according to their positions.



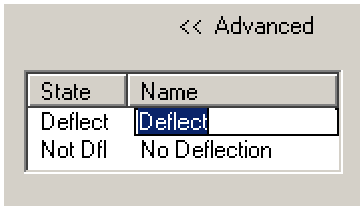
Here, one might add ("+") a number of states (or remove by highlighting and hitting "–").

Define states by the wavelength of insertion (inclusive), and the SAM state.

SAM states are as follows:-

•Deflect- relay light to the exit *Opposite* entrance slit
•No deflection- relay light to the exit at right angles to the entrance slit

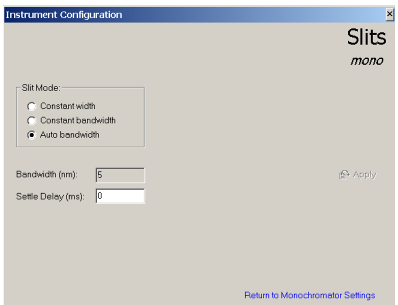
In advanced>> can be named the two SAM states for easier setting up.



Settle delay of 1000ms is sufficient. states are

6.5.6 Motorised slits

The properties page of the motorised slits is as follows:-



There are three available modes of operation:-

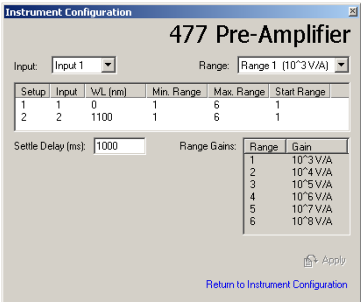
•constant width, input required dimension
•constant bandwidth, input required bandwidth
•auto, sets the bandwidth to the step size defined in the scan setup page

It should be noted that having calibrated a system in auto mode at a given step size, to change the step size would invalidate the calibration.

A settle delay of 100ms is sufficient.

6.5.7 AC Pre- amplifier

The properties page of the AC pre-amplifier are as follows:-



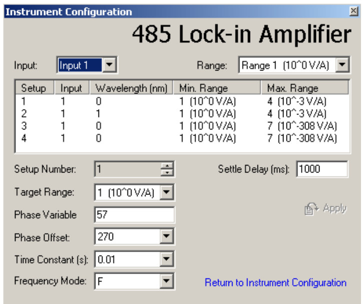
Two set ups are possible, for each of which can be defined the input, start wavelength (0nm for first setup) and gain ranges employed.

It is recommended to use all ranges, 1 (min) to 6 (max). Set the start range as the min range.

A settle delay of 1000ms is sufficient.

6.5.8 Lock-in amplifier

For the lock-in amplifier, four set ups are possible, for each of which can be defined the input used, start wavelength (0nm for first setup), gain ranges employed, and set up of the lock-in amplifier.



It is recommended to use min range 1 and max range 4 at all times.

The lock-in amplifier takes a reference signal from the optical chopper and compares this with the signal obtained from the detector under consideration.

It is therefore question of determining the relative phase difference between both signals to recover the detector output.

The phase parameters as to device setup are obtained by the following means.

Optimising Lock-in performance

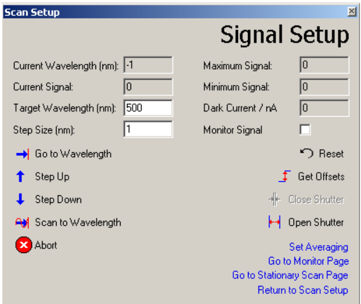
For each detector in turn it is good practice to optimise the lock-in performance, leading to parameters for the given detector which can be given to Benwin+.

In an attempt to recover full signal from sample, one must determine the relative phasing of the chopped electrical and optical signal, characterised by a quadrant and phase angle. Due to path difference, the phase angle may differ from shallow to wide grating angles and movement of the sample plane.

The following optimisation procedure ought to be performed at a position in the spectrum where large signal is expected, the antipodes of the scan may then be considered to see if the phase angle varies significantly.

The procedure is as follows:-

•Go to Scan/ Signal Setup and set the target wavelength to the desired wavelength and select Go to wavelength



•Ensure that large slits are being used to ensure a large signal arrive at the detector, and that the appropriate combination of source, gratings and detector are in place.
•Monitor the output of the lock-in via channel A on the 417 unit.
•The output may oscillate for a short time before becoming stable as the unit locks-in.
•There may be need to change the sensitivity level of both the 485 and the 477. This is done manually by pressing the RTL button on the appropriate unit then use the buttons to change as appropriate.
•Press RTL on the 485 to permit local use, then push the 90/180° button a few times.
•You should observe the sequence positive large signal-near zero signal- negative large signal- near zero signal as you go through the four quadrants.
•Go to one of the quadrants where there is near-zero signal
•Adjust the phase control knob such that the output signal goes down to zero.
•Press the 90° button to switch through multiples of 90° until a positive reading is seen on the 417.
•The positive reading is the peak value of the input signal, the 485 is correctly phased.
•Note the phase offset angle of the quadrant in which the positive reading is found, and the angle in the variable phase LCD.
•Repeat as necessary at different points in the spectrum.

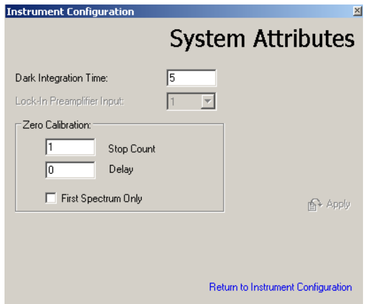
Having obtained the phase parameters, one may create on of four set-ups in the lock-in page, instructing the software to use the given parameters for a given wavelength region of interest.

Use the up/ down arrows next to the setup number box in the lower half of the page to scroll through the four possible setups, and use the top table to specify which setup is in use and from which wavelength this should be applied.

6.5.9 "Miscellaneous"

The miscellaneous page is as follows.

The dark integration time, the time over which dark current is integrated is factory set to 5 seconds and should be sufficient.



6.5.10 Changeover wavelengths

It is important to note the mode of use of the changeover wavelengths in Benwin+, notably that the gratings behave in a manner different to all other items.

The specified changeover wavelength for a grating is the maximum wavelength of use, and is inclusive.

The changeover points of all other devices are defined as the start point of the new state, and are also inclusive.

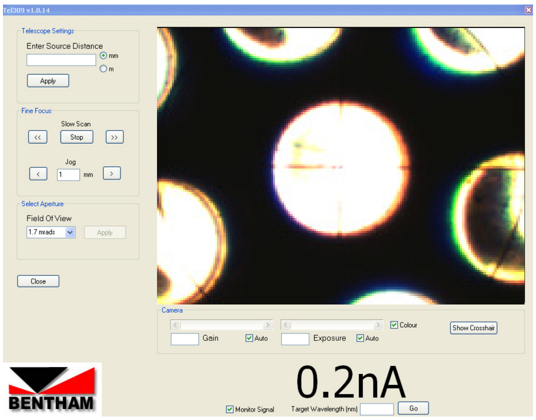
Gratings should change therefore at x-0.1 nm, whilst all other elements at x nm.

It is important to synchronise such changes as those of SAMs, detectors and amplifier inputs in use.

It is also of use to make a number of changes at one particular wavelength rather than having a series of changes throughout a scan.

6.5.11 TEL309 Utility

Accessed via the utilities menu, the TEL309 utility gives access to the following page:-



•***Enter source distance-*** type in measurement distance. Hitting apply will prompt the user to install the correct lens

•***Fine focus-*** permits the user to improve the focus of the source by the TEL309. Jog moves by steps, scan continuously moves.

•***Select Aperture-*** type Select 1.7 or 11mrad field of view, hit apply to select

•***Camera-*** suggested to leave in auto gain and exposure

•***Show crosshair-*** select alignment crosshair from aperture wheel

•***Monitor Wavelength/ Target Wavelength/ Go*** select monitor wavelength

•***xxnA-*** Measured photocurrent.

The latter function is used when aligning a source with the telescope, and uses the measured signal at a given wavelength as a means of determining the position of maximum output. The wavelength to choose must of course be in the range of output of the source, for white light sources 555nm (green) is usually a good location.

All settings of the TEL309 are found in the tel309Settings.ini file in the Benwin+ folder- not to be modified.

6.5.12 Alignment utility

The alignment utility serves to aid in alignment of a source, using the measured signal as a reference to optimise postion.

This function is accessed via the utilities menu.

To use the function, it is necessary to set the monochromator to a monitor wavelength; one should go to scan/ signal setup, select a suitable wavelength for monitoring the source output (such as 555nm), and hitting the “go to wavelength” button.

6.5.13 Correction calculator

Spectroradiometer calibration factors are obtained from the measured photocurrent $I_{ref}(\lambda)$ of a device of known response $R_{ref}(\lambda)$; this provides the multiplying calibration factor $R_{ref}(\lambda)/I_{ref}(\lambda)$ to convert the measured photocurrent of a device under test, $I_{test}(\lambda)$ to a correctly calibrated result.

There exists a few cases where a spectroradiometer system should be calibrated with two calibration standards, for example, to cover a wide spectral range.

In such a case, the two calibration factors must be concatenated to provide a single one covering the full spectral range of measurement.

This add-on, to be used in the framework of Benwin+, has been written to ease this dual calibration procedure.

Dual Calibration
From the measurement of the two calibration sources, having a common spectral region of overlap, two sets of calibration factors are obtained. Of the two calibration factors, one is taken to be absolute, and the other relative, ie the position of the latter with respect to the y-axis can be altered to yield an absolute result. A cross-over point is determined, as which the relative calibration factors are normalised with the absolute. Before concatenation, it is necessary to limit the upper extent of the one factor and the lower extent of the other to ensure that for each wavelength there is only one calibration factor.

An example is the calibration of a spectroradiometer in spectral irradiance, over the UV-visible range, with a deuterium and a quartz halogen lamp.

The former provides a relative calibration factor in the range 200-400nm and the latter an absolute calibration factor in the range 300-800nm.

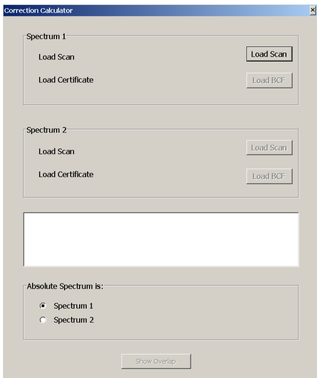
Where the measurement step is other than that of the calibration certificate, a cubic spline interpolation is applied.

This procedure supports the use of a varying step size through the scan, using Benwin+ customer wavelength files.

Calibration Procedure
It is recommended to perform a number of measurements with both calibration devices over the appropriate spectral ranges, and to average the result to be used for system calibration. This average should be saved (having deleted the original measurement values), and the following procedure followed:

With system initialised, ensuring the files to be loaded are not currently open in Benwin+, go to utilities, select correction calculator to view the following window

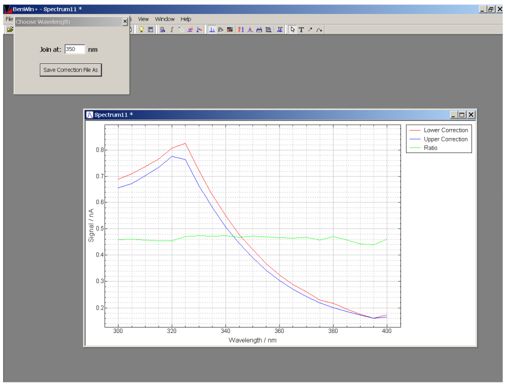
For each spectrum
•Hit load scan, select saved measurement file
•Select corresponding bcf file
•Select which of two spectra absolute
•Hit show overlap

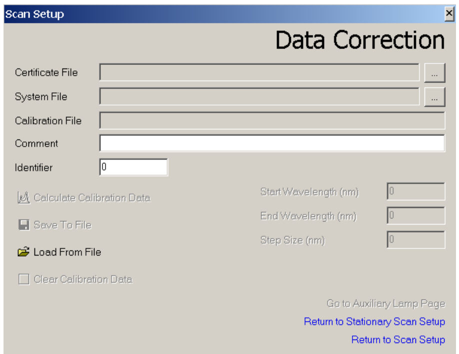


A Benwin+ window is launched showing the two correction factors and a normalised ratio of the two. The default normalisation point is the mid point. Based on a consideration of the ratio this value may be changed.

•Where required, input different cross-over
•Hit save correction file as… and give appropriate name

To implement this calibration factor
•Go to Benwin+, data correction
•Hit load from file
•Load just saved correction factor
•Use Benwin+ as normal





6.5.14 Luxmeter Utility

The luxmeter utility permits using input two of the second amplifier with a photometric detector for use as a luxmeter.

The calibration values of the detector are to be defined in the luxsettings.txt file, in units of lux/nA.

The add-on reports the measured illuminance in lux.

6.6 Measurements and utilities

6.6.1 Introduction

Benwin+ is a general purpose spectroradiometer software, wavelength scans being its habitual use.

Other functions include setting the monochromator to a given wavelength, timed scans at a given wavelength, scans according to a schedule, system calibration, and relative measurements.

Spectral scans involve the initial measurement of the system with respect to a reference. This reference may be a lamp of known output, a reflectance standard or a 100% “no-sample” measurement.

By comparing the measured signal obtained as a function of wavelength with the reference, can one determine the nature of an unknown sample.

The system therefore effectively measures the detector photocurrent under stimulation by the source, as a function of wavelength, which is therefore a convolution of the source output, the spectral response of the input optic, the monochromator (mirrors and diffraction grating) and of the detector.

As shall be seen in the next section, an advanced menu gives access to change items such as zero

6.6.2 Hardware operation

The initialisation procedure establishes communication with all hardware components, and moves the monochromator to a known reference point.

For M300 and DM150 monochromators, the gratings are moved to a maximum positive limit the corresponding wavelength of which should be input to the software at installation.

For (D)TM300 monochromators, the procedure moves the monochromator moves the turret to a negative mechanical limit, the software being instructed via the system.atr file the number of steps from this point is the zero-order position of a given grating.

Now, in most systems there exists a filter wheel, in position six of which is a blank to shut off the input to the monochromator. This is used in the determination of the detector dark current, and to protect the detector from continual exposure.

When scans are launched, it is important to perform the zero- calibration procedure.

This procedure shuts the input to the monochromator. In the first instance sets the current amplifier to maximum gain range (ranging to a lower gain range if this range is in overload). When stable, the output of the ADC is read.

This constitutes the detector dark current. The current amplifier is then set to its' minimum gain range, and the ADC read. The signal measured does not come from the darkened detector at this point, what is registered is the offset of the detection electronics. The 20,000 count ADC has ~400 counts reserved for negative-going noise signals. With no stimulation therefore, the system should read ~400 counts. It is important to realise the importance of ensuring this offset is taking into account. Consider for example a large signal in a higher gain range, say 18000 counts, ranging to a lower gain range, where the counts may be 1800.

The relative impact of not subtracting the 400 count offset leads to discontinuities in the spectrum should zero-calibration not be taken into account.

Should zero-calibration be not selected, provided that the system has performed at a previous point this routine, the same values shall be carried through at all times.

This is not recommended, particularly in the case of for example photomultipliers, whose response is very temperature and condition dependant.

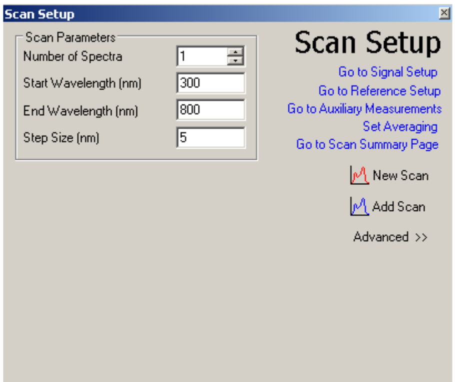
In the scan parameters page, it is recommended that the zero-calibration routine be applied, that the amplifier be permitted to auto-range, that the shutter is closed post-scan, and that the monochromator is returned to the start wavelength for the next measurement.

Furthermore, where add-on modules are employed, ensure that appropriate pre-/ post-scan module fields are selected.

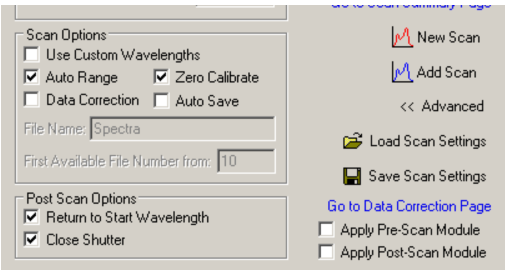
6.6.3 Scan setup

Scan/ Scan setup

Spectral scans are initiated by going to the Scan menu and selecting Scan setup to reveal the following:-



•Enter the wavelength range required
•Select bandwidth required
•Select number of scans required
•Click on advanced>> for further features:-



•Ensure that zero calibration is selected. This determines ADC offset and dark current at beginning of scan.
•Ensure that autorange is selected, permitting the amplifier, to change gain range where appropriate.

•It is of good practice to have close shutter and return to start wavelength selected.
•Should it be desired that all spectra are saved, select auto save and define file name prefix and number suffix
•Click on new scan for measurement.

When performing initial measurements of a calibration standard, ensure that data correction is not selected- this uses the calibration mode of the software not required at present, the y-axis of the scan window once launched should read Signal (nA).

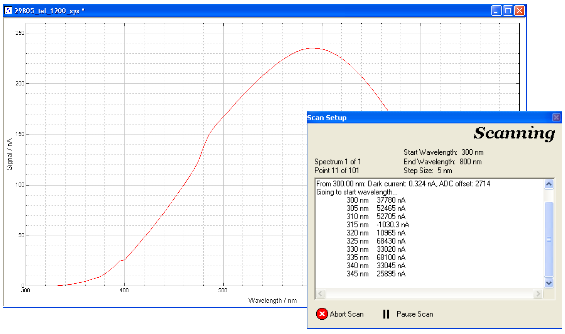
Having performed measurements of the calibration standard, and having implemented a correction (see below), ensure that data correction is selected to determine the corrected output of unknown sources.

The following window shall be seen in the foreground, detailing the progress of the scan, whilst a spectral plot will appear in the background.

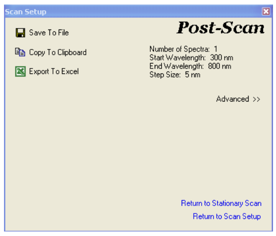
The shape of the uncorrected scan will vary depending upon source, gratings, etc, but it is normal that there be relatively sharp features, with loss of response towards the ends of the spectrum.

Furthermore, a slight discontinuity may be seen at the insertion of order sorting filters.

All of these features “calibrate out”.



At the end of a scan, you shall be presented with the following screen.



At this point one may, if desired choose to export the spectrum to excel (either for viewing, to perform calculations or to run macro which may be specified), or one may simply close this window.

If autosave should not be selected, ensure that the current spectrum is saved.

6.6.4 System Calibration

Scan/ Data correction

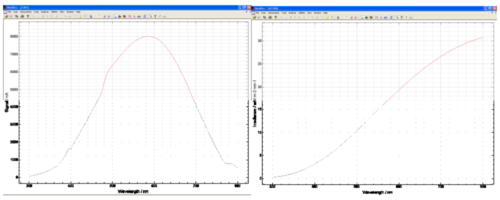
This refers to calibration of sources or detectors against standards. For measurements against reflectance etc standards please see section §6.6.6.

The measurement of any unknown source with a spectroradiometer, or the response of an unknown detector means nothing without comparison to a standard such as those obtained or compared with scales as defined for example by the National Physical Laboratory.

Such measurements require a first scan of a standard prior to measurement of the unknown device.

An example of this can be seen in the following figure, the irradiance of a lamp being required.

The upper scan is the throughput of the monochromator system when viewing the unknown lamp, having actual irradiance displayed in the lower spectrum.



The ratio of the calibration data showing the true device spectrum, to the system measurement, yields a wavelength dependant system correction factor. All future measurements ought to be multiplied by this correction curve to yield a true reflection of the source unknown device spectrum.

This rationale applies for the determination of detector responsivity.

It is also of importance to reflect the quantity of the calibration measurement, whether it be irradiance, radiance etc.

This correction, and subsequent presentation of data in correct quantities and units, is implemented in Benwin+ via the data correction page.

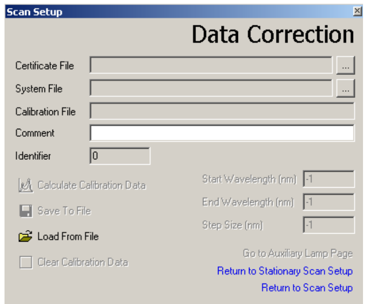
Firstly to apply data correction two files are required-

•A *.bcf Bentham certificate file of the source calibrated results with measured quantities and units
•A *.ben, system file, measurement of the unknown device in the same step

The procedure is as follows:-

•Perform scan over desired spectral range of standard source

•Ensure that data correction is not selected and that the units of the measurement are in nA
•Save scan.
•Go to Scan/ data correction page.

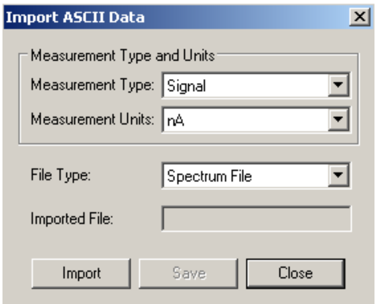


•Using … button select appropriate *.bcf file for device
•Select just-saved scan as system file.
•Hit Calculate calibration data.
•Save to file
•When prompted do you wish to apply data correction click YES
•Return to scan setup, and then scan as normal.
•Note that the y-axis should reflect the correct quantity to be measured.
•Ensure that the next time that a comparison to standard be performed, that data correction is NOT selected.

One may view the *.bcf file by selecting open/ all files and find the bcf files in the Benwin+ calibration folder.

If you have no bcf file, you can create one by the following process.

•Prepare your calibration standard data as a two column ascii file with no header nor footer, wavelength in the left column, measurement in the right.
•Save this file.
•Go to Benwin+, file, Import.



•Select type, units and quantity of measure, select certificate file and import.
•Chose the file of your data and save in the Benwin+/ calibration folder.

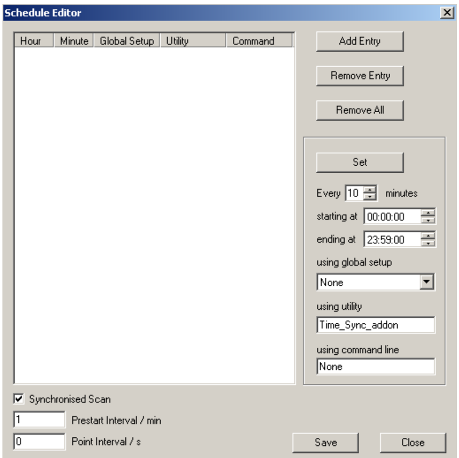
6.6.5 Scheduled Measurements

6.6.5.1 Setting a schedule

With data correction in place:-

Tools/ Configure schedule

Unattended measurements may be configured in the Tools/ configure schedule mode.



One can then add one-by-one entries using the upper add entry button, or using the lower set panel, define start and stop time, and interval. Note the minimum is 5 minutes interval. Hit set to define measurement points in large window.

One can also define a synchronised scan to force a spectral measurement to follow a given time profile, making dark current measurements in prestart interval and defining time per wavelength points.

When file ready hit save, and save to schedules folder. File extension *.sch.

One can edit more easily in excel for example, save as text then save in notepad as all file, *.sch.

6.6.5.2 Running a schedule

Tools/ Schedule mode

To run a schedule, return to tools/ schedule mode and select saved schedule file.

The status bar at the bottom of the screen indicates when the instrument is operating in scheduled mode. The time of the next acquisition is also indicated. Schedules shall repeat at the given times each day until stopped.

The spectra files acquired during scheduled mode are automatically saved with a filename of the type year-month-day_hour-minute.ben e.g. 20050514_1450.ben

Furthermore, provided that saving the time_sync in ascii or excel has been selected a file of similar name format shall be saved in the folder locations as per the add-on.

The Schedules contains a log file of each days scheduled spectra - *.log.

The log file lists the filenames of the acquired spectra, the start and end time of each spectrum and the detector dark current. The other two reported values are not here recorded.

6.6.6 Reference Measurements

Scan/ Reference setup

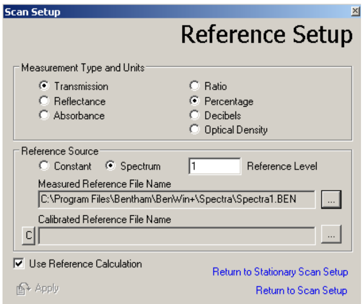
Reference setup can be found in the scan menu. This permits the direct measurement of transmission, reflectance and absorbance of samples.

No calibration correction is applied here. Of interest is the comparison of the raw measured signal with either no sample (for transmission and absorbance) or a standard (for reflectance) in place, and then with the sample under test in place.

In the case of reflectance, the standard used may be presumed to have 100% reflectivity, or one can specify a calibration file with the true reflectance of the standard. This file should be in absolute units.

The measurement procedure follows:-

•Go to scan/scan setup
•Ensure in advanced>> that data correction is NOT selected
•Perform scan over required spectral range
•Save file
•Go to scan/reference setup



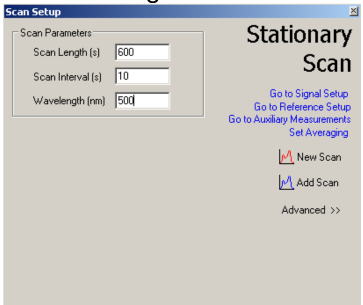
•Select required measurement type and unit
•Select reference to apply , constant (inputting reference level) or spectrum
•Use "…" to load just saved reference spectrum
•In the case of reflectance, should a calibration file be held for the standard, load this file using the …
•Select use reference calculation
•Return to scan setup
•Perform scans in the usual manner
•To use another reference file, use the … button to select other file
•To perform a new reference level, ensure that "use reference calculation" is switched off
•To switch of calibration correction, hit C button to remove file

6.6.7 Stationary Scans

Scan/ Stationary scan setup

It is possible to perform time-based scans at a fixed wavelength. This is particularly interesting when for example monitoring a lamp to determine warm- up stabilisation period, or for example to measure the transmission of a photochromic material during or after activation.

Go to scan/ stationary scan setup to reveal the following:-



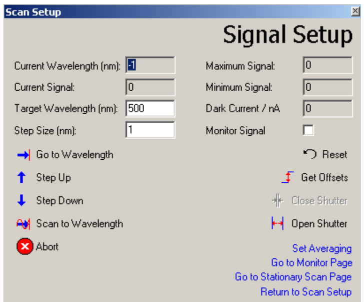
Define scan length, scan interval and monitor wavelength. It is sometimes useful to perform a spectral measurement of an unknown source beforehand to determine the spectral output, and therefore to determine the wavelength of monitoring.

In advanced, one can select whether data correction be applied or not. Ensure that auto ranging and zero calibration are selected for correct measurement. The scan interval should not be less than the ADC read interval.

6.6.8 Signal Setup

Scan/ Signal setup

The signal setup page permits moving the monochromator to a given wavelength, of use for certain measurements, and also useful when aligning optics.



Input the desired wavelength in Target Wavelength and hit Go to wavelength. Note that one might monitor the zero order contribution by typing 0 for the wavelength.

Note that here there may be a large signal which may be of consequence with the detector in use (particularly if a bi-alkali photomultiplier is used, for which high signal stimulation might cause hysteresis effects).

Once at the given wavelength, the filter wheel opens the shutter.

Selecting the monitor signal box ranges the amplifiers to determine the current signal.

One might also define a step size, and manually scan over a spectral range by hitting the scan up/ scan down buttons. Note that the monochromator control is designed such that a given wavelength be reached in one direction only, that of increasing wavelength.

This is to ensure the best wavelength calibration. When scanning down the wavelength scale, the system goes beyond the wavelength selected to approach in the increasing direction.

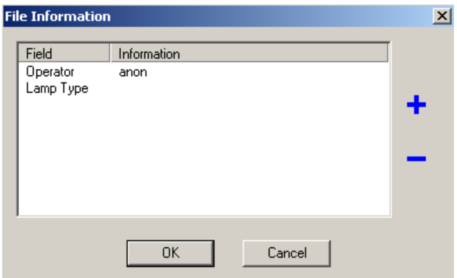
6.6.9 Signal monitor

Scan/ Signal monitor

The signal monitor opens the shutter and monitors the signal at the current wavelength. A graphic with auto-ranging y-axis shows the current signal and is update as fast as possible.

6.6.10 Set file information

Scan/ Set file information



One can associate information with each scan by going to Scan/ file information. Here one can define a number of fields hitting the + button, double clicking on the field entry on each line to edit to, for example, Operator, Lamp type etc. One can pre-define the file information to prevent re-typing information common to each measurement. Highlight and hit the – button to delete a field.

With Use file information selected, on starting a new scan a window prompts for the entry of the required file information values. File information is saved with scan data.

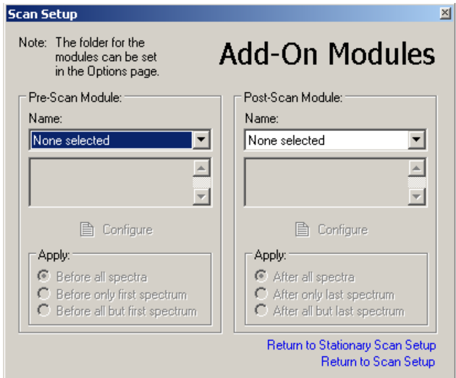
6.6.11 Add-ons

Scan/ Add-on modules

In order to increase the flexibility of a given system, add-on modules permit the interfacing of for example the control of further instruments, as part of Benwin+, or specific data analysis post-scan.

A guide to add-on modules is provided in appendix 4, for further information, please contact Bentham.

Add-on module dlls should be placed in the Benwin+/ Add-ons folder. They can be implemented via the add-on modules page, and selected as either pre- or post- (or both) add-on modules. Pre-scan modules are used in instances where control or measurement during scans is required, post-scan modules when calculations are involved.

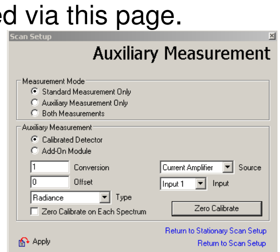


6.6.12 Auxiliary measurements

Scan/ Auxiliary measurements

It is possible to collect data from a source other than the principal monochromator detector. This source might be obtained via either a Bentham two input current amplifier or relay unit, or via an add-on.

Should a calibration factor be associated with this auxiliary measurement, this may be defined via this page.



Define whether standard, auxiliary or both measurements are to be performed.

Define whether a calibrated detector or add-on module is employed.

Data are acquired at each point in the ranged defined as a scan.

Should a calibrated detector be employed, it is of question to define the source, input, conversion factor, offset and measurement type.

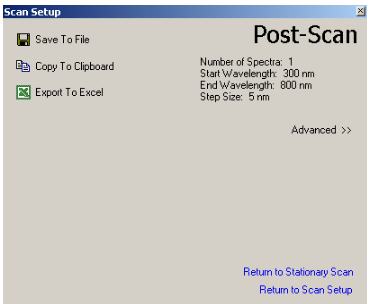
Covering the detector, one can hit the zero calibrate button to take the dark current of the source.

The measurement type can be either

•**Radiance** – mW sr^{-1} m^{-2} nm^{-1}
•**Radiant Intensity** – mW sr^{-1} nm^{-1}
•**Irradiance** – mW m^{-2} nm^{-1}
•**Radiant Flux** – mW nm^{-1},
•**Detector response** – A W^{-1} nm^{-1}

6.6.13 Post-scan

A scan having finished, one is presented with the following window:-



If autosave was not selected, save the file now.

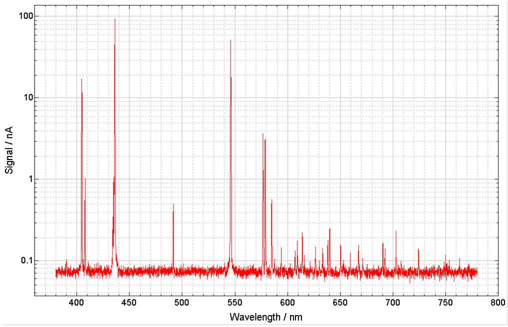
In the following sections are given information on the three Benwin+ data views, and the direct exportation of results to Excel.

6.7. Spectrum View

View/ Spectrum

6.7.1 Introduction

This default view presents a view of the spectral distribution of the source, as a function of wavelength (or as a function of time in the case of time-based scans).



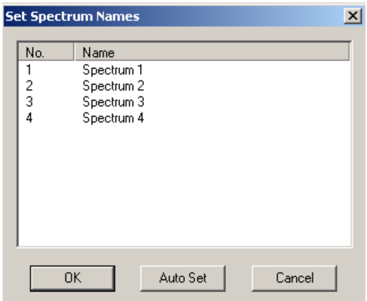
Having performed a scan, within this view the data may be analysed via functions in the analysis menu, or using a right mouse key short cut button.

These functions follow, starting with the analysis menu.

6.7.2 Set spectrum names

Analysis/ Set spectrum names

One may either autoset file names or change each entry manually.

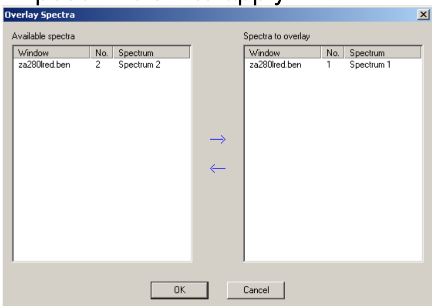


6.7.3 Overlay spectra

Analysis/ Overlay spectra

Having more than one spectrum window open, it is possible to superimpose selected scans into a given window.

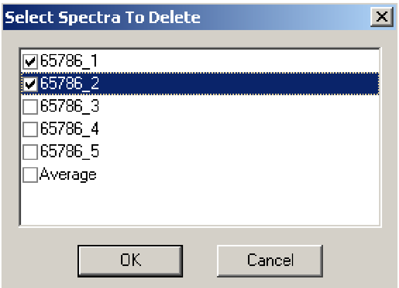
Those available spectra are found in the left hand window, may be highlighted and the → arrow used to place the spectrum in the list to superimpose. Hit OK to apply.



6.7.4 Delete spectra

Analysis/ Delete spectra

One may delete spectra from a multiple-spectrum window. Check off spectra for deletion, hit OK.

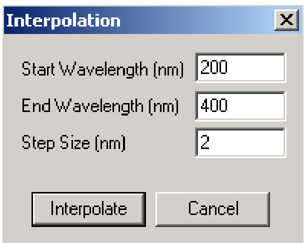


6.7.5 Interpolate

Analysis/ Interpolate

One might apply a cubic spline to interpolate (or extrapolate) given spectral data.

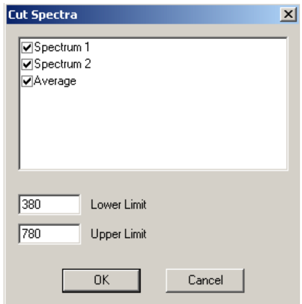
•Go to analysis/ interpolate
•Modifying the start or stop wavelengths truncates the scan
•Enter the desired step size.



6.7.6 Cut

Analysis/ Cut

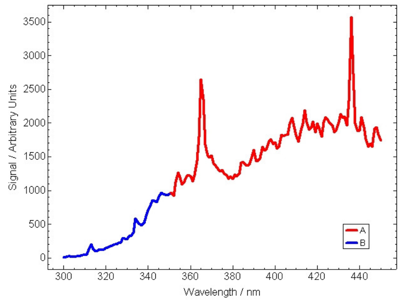
Check off from the list the spectra desired to truncate, define the lower and upper limits, then hit OK.



6.7.7 Concatenate

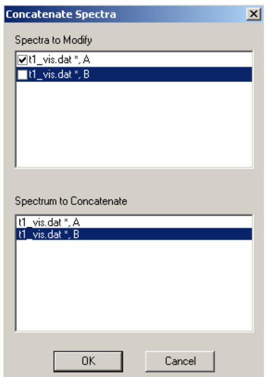
Analysis/ Concatenate

One can concatenate two spectra, to obtain a single spectrum.



.

The spectra need not be continuous, but where a sub-set of the values are not exclusive, the latter sub-set is not modified, the remainder of the set being concatenated.



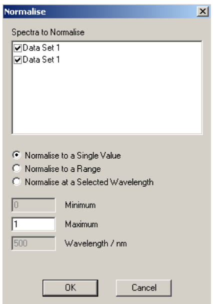
6.7.8 Invert

Analysis/Invert

Select to obtain a mirror image in the plane of the x-axis of a given spectrum.

6.7.9 Normalise

Analysis/ Normalise



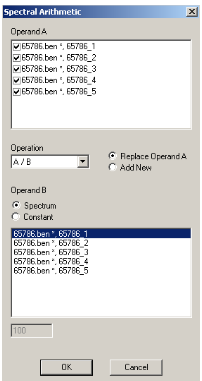
One may normalise selected spectra to:-

•A single value, defined as the maximum,. set usually to unity
• A range, define maximum and minimum limits
•A selected wavelength, define the wavelength and the maximum wavelength

6.7.10 Spectral arithmetic

Analysis/ Spectral arithmetic

Having one or more scan windows open, one can perform simple arithmetic, either multiplying a spectrum by a constant or another spectrum.



With the window of the first spectrum active, go t o Analysis/ spectral arithmetic

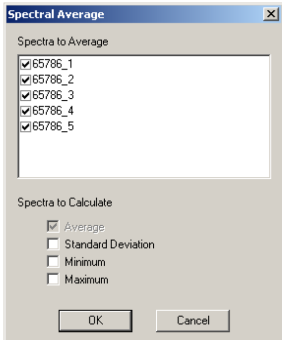
Select the spectrum (or spectra) for OperandA, the operation required, and for OperandB select either a constant (defined lower) or another spectrum.

Select Replace or add new spectra, then OK.

6.7.11 Spectral average

Analysis/ Spectral average

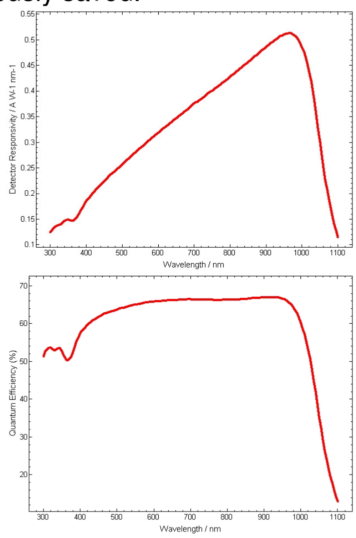
Having performed a number of scans of a given source, one can perform a spectral average, determining also the standard deviation and two spectra based on the minimum and maximum values at each point. These results are labelled accordingly, and are presented on the active spectrum window.



6.7.12 Quantum efficiency

Analysis/ Quantum Efficiency

In the case of detector responsivity (A W^{-1} nm^{-1}) the responsivity results may be converted to quantum efficiency, defined as the ratio of electrons extracted for the number of incident photons. This process is non-reversible, ensure that the original detector responsivity has been previously saved.

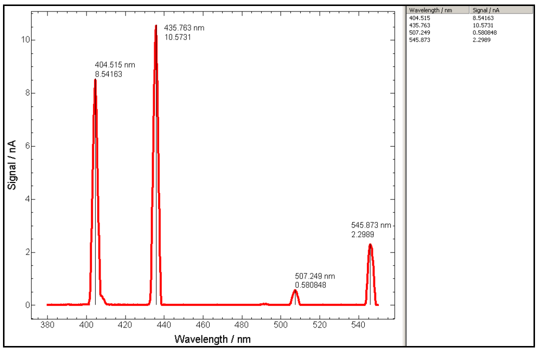


6.7.13 Peak picker

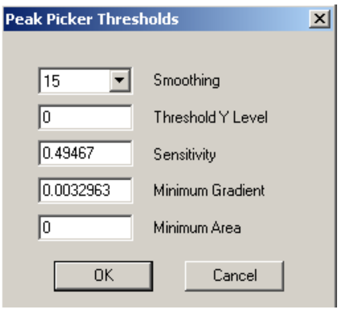
Analysis/ Peak Picker

Having performed for example a scan of a line source, the peak picker function may be used to determine the wavelength position of these peaks**.**

Typically using the auto-settings function should find the peaks present. The results are noted on the graph, a measurements window to the right of the spectrum window also displaying the results.



Should certain peaks not be found using the auto settings, then the set thresholds window can be accessed.



The functions are as follows.

Using the auto-settings function overwrites all changes to thresholds.

Smoothing: Reduces errors due to a noisy spectrum. Broad peaks should be smoothed with a larger number of sample, the converse for narrow peaks.

Threshold Y Level: Enables the rejection of peaks whose height above a local baseline is below that value.

Sensitivity: The Sensitivity threshold allows the user reject peaks whose absolute height is less than a set value.

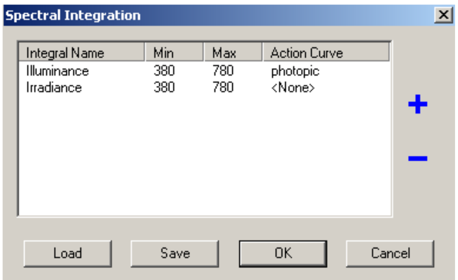
Minimum Gradient: The Minimum Gradient (Value >0) threshold is used to define the peak edges. Points at which the absolute gradient are greater than the Minimum Gradient are considered to be peaks.

Minimum Area: Peaks with an area less than the Minimum Area are rejected. This discounts delta-function peaks such as caused by cosmic events.

6.7.14 Spectral Integrals

Analysis/ Set spectral integrals

Spectral integrals and action spectra can be applied in the Analysis/ Set spectral root.



+ add integrals, define name, spectral range, and action spectra. Action spectra are two-column ascii files (wavelength, value) saved as *.ACTION in Benwin+ folder.

One may define a group of integrals and save for use later.

For the first time go to Analysis/ Calculate spectral integrals to view results.

Thereafter, Benwin+ will present results automatically. The data are also saved in the *.ben file.

6.7.15 View menu

View/ Spectral data

Through the view menu, one can toggle to further views as described in the following sections, as well as looking at spectral data and viewing/ adding markers and cursors to determine the positions of features.

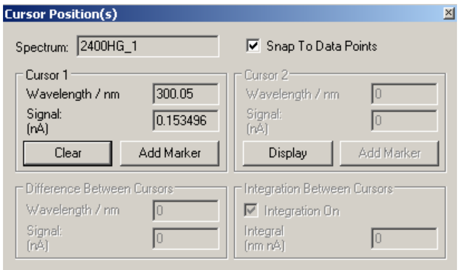
Markers may be automatically positioned using the peak pickers function or via cursors.

One can view the numerical data by selecting view/ spectral data. Re-select to remove the measurement data.

View/ Cursors

One can place up to two cursors on the canvas of the spectrum to manually probe the measurement results.

The cursors are accessed via view/ cursors.



Controls of the two cursors are on either side of the window.

Hit display to obtain the cursor which may be dragged in place with the mouse. The wavelength and signal of the cursor position is displayed.

One may choose to add a marker at that position. When two cursors are active, the lower section of the cursor window shows the difference and integration between the cursors.

When multiple spectra are present in a given window, the keyboard up/ down arrows selects the curve under consideration.

Hit clear to remove the cursor from the graphical view.

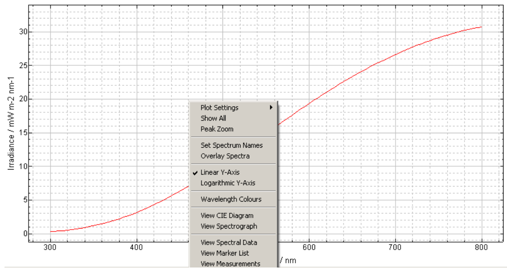
View/Marker list

Provides the user with a list of extant markers in a window.

6.7.16 Further features

Further menu features, including short-cuts to some of the above are obtained from a menu activated with right mouse click over a spectrum window.

These items are as follows:-



Plot settings: Define the aesthetic aspects of the graph, line colours, labels etc.

Show All: A zoom is provided by pushing left mouse button, holding down the button one can create a zoom box whilst moving the mouse to view a particular region of the spectrum. Show all returns to a view of all data.

Peak Zoom: Automatic finding and viewing of peaks

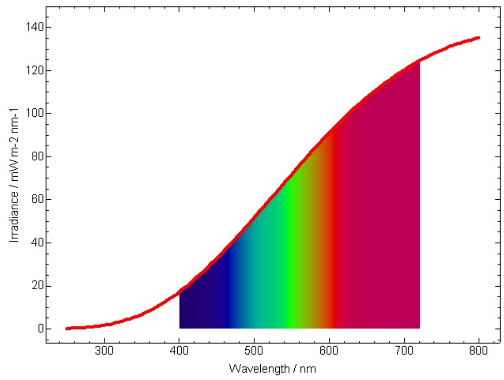
Set spectrum names: See §6.7.2

Overlay spectra: See §6.7.3

Linear/ lograthmic axis: Set y-axis as linear/ logarithmic axis

Wavelength colours:

Superimposes wavelength colours to a scan over the visible region.



View CIE/ spectrograph: Toggle between views

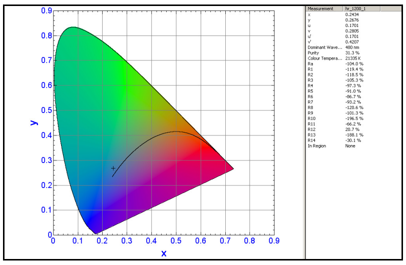
View spectral data/ marker list/ measurements: Presents to right of spectrum window spectrum values, markers and calculated measurement values (spectral integrals).

6.8. CIE diagram view

View/ CIE diagram

6.8.1 Introduction

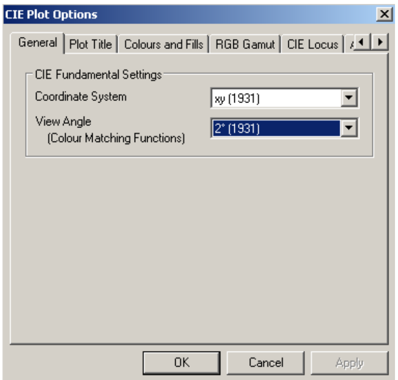
Active when measurements are performed over the entire photopic region, 380-780nm, this view calculates the colorimetry of a given spectral shape, indicated on a CIE diagram. Colorimetry parameter values are returned in a table to the right of the graphic.



This view can be set as default in the ***Tools/ Options*** window, select “Automatically show CIE diagram after scan”.

6.8.2 CIE diagram Settings

This window can be accessed via pushing the right mouse button whilst the cursor is over the CIE diagram.



Options are as follows.

General: Set the coordinate system and viewing angle to be used when plotting the CIE diagram.

Plot Title: Apply or not title to graph, edit text properties.

Colour and Fill Settings: Set the colour for the background of the CIE diagram. The fill type of the diagram is also selectable - the default being RGB Colours.

A gamma correction function can also be applied to take account of the brightness characteristics of the display monitor. The default setting is to use gamma correction with a typical value of 1.6.

RGB Gamut Settings: The RGB colour system used to fill the CIE diagram can be set. The settings depend on the monitor being used.

If the Fill RGB Gamut Only checkbox is selected then only those colours reproducible on a computer monitor will be displayed. A locus can be drawn around this RGB gamut. The line style of the locus is user-defined.

CIE Locus Settings: This page sets the style of the locus around the CIE diagram. Wavelength markers can also be The text and font settings of the markers can be adjusted.

Axis Title Settings: Select whether to show each of the x and y-axis titles, defining font settings.

Axis Settings: Set which axes are shown and which colour to use. The data ranges can also be set, although the displayed region can also be set by the zoom function.

Axis Tick Settings: Set the style of the ticks axis ticks.

Grid Line Settings: show/ not major and minor grid lines on each of the axes, defining colour and style. The colour and style of the major and minor lines can be set.

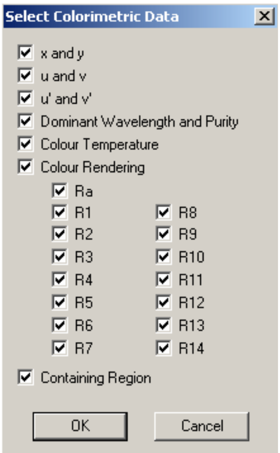
6.8.3 Set colorimetric data

Analysis/ Set colorimetric data

Define which parameters should be reported with the CIE diagram.

Options are:-

•Colorimetric data in different coordinate systems
•Dominant wavelength and purity
•Colour temperature
•Colour rendering
•Containing Region (see next section)



6.8.4 CIE Colour Regions

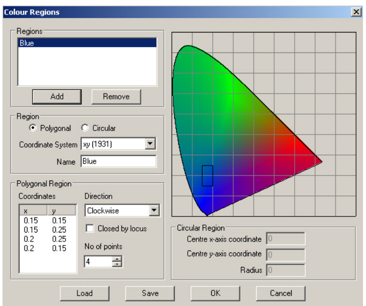
Analysis/ Set colour regions

Specific colour regions of interest may be defined an named, such that, having finished a scan, Benwin+ might, in the CIE diagram view report in which, if any, region a given source falls. The procedure for defining regions is as follows.

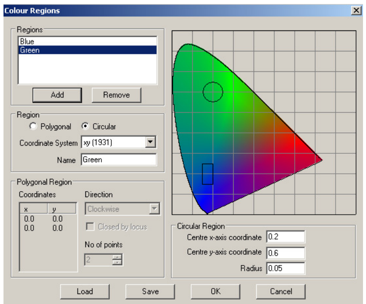
•Choose Polygon or Circular
•Define co-ordinate system
•Type in name

For polygon:-

•Define direction
•Define number of points
•Double click on x and y values in table to edit
•Hit add to accept



For circular:-
•Define x and y co-ordinates
•Define Radius
•Hit add to accept



A group of regions may be saved, and loaded as appropriate.

Having performed a scan, and presuming that containing region is selected in set colorimetric data, the region in which lies a measurement data point shall be reported.

6.8.5 Further features

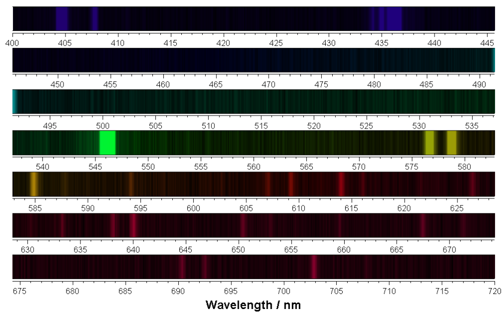
In a similar manner to the spectrum view, one may zoom into specific regions using left mouse click and drag to define region of interest.

Right mouse click gives access to changing the settings and defining colour regions.

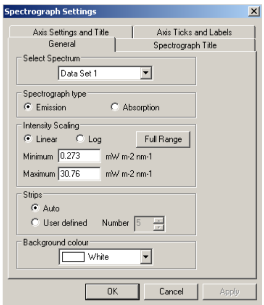
6.9. Spectrograph view

View/ Spectrograph

Of use when measuring line sources, the spectrograph view presents a line spectrum view of source spectral features.



Right mouse click over the spectrograph gives access to properties.



General: Define spectrum as being emission or absorption type, apply linear/ logarithmic scale, define scale, range, and number of bars in spectrograph.

Axis settings & title: Define axis and fonts

Axis ticks and labels: Define ticks, labels and fonts

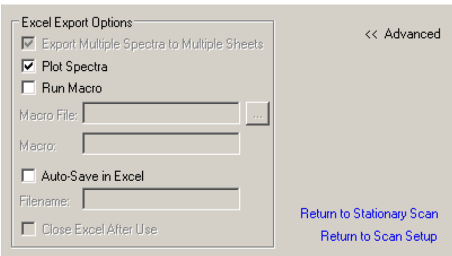
Spectrograph title: Add title, defining style.

6.10. Export to Excel

It is possible to export scan results to Excel, either at the end of a scan or via the scan menu.

Via the post-scan page

In advanced>>, one can edit the Excel export settings.



Having performed multiple scans in one window, the Export Multiple spectra to multiple sheets button becomes active. This permits the choice of exporting each spectrum to an individual worksheet, or placing all in one worksheet.
One may choose whether or not to plot the spectrum on exporting to Excel.
Should a macro be required, select “Run macro” to run pre-defined macro (see appendix 4 for information on writing macros).
Define the macro file using the “…” button to select, and define the name of the required macro.

One may choose to autosave in Excel, in which case a filename is required.

Else, one can export via

File/ Export/ Export to Excel

6.11 Use of Benwin+ on Desk Computers

It is possible to install Benwin+ on a desktop computer to view measurement results extra-laboratory.

•Load Benwin software CD into computer.
•Double click on the set-up launcher icon, which shall take you through the set-up process.
•You may now run Benwin+ for use to load saved spectra etc.
•Initialising will not however work

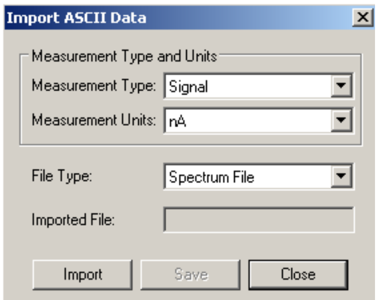
6.12. Menu reference

The following is a reference of those Benwin+ specific menu items.

6.12.1 File

An expanded menu is available when a spectrum opened.

Import Ascii data: Import ascii two-column ascii file wavelength in left column, values in right, for preparation as Benwin+ spectrum, certificate or calibration file.



Using pull down menus, define measurement type, units and file type.

File types are:-

*.ben- Benwin+ spectrum file
*.bcf- Benwin certificate file. When applying data correction, the certificate file must be in this format (see § 6.6.4)

Import Colorimetry data: Import data from ascii file.

Export to Ascii: Export spectral results to two-column ascii file (*.dat)

Benwin+1.0 file:- Benwin+ spectrum files contains not only spectral file information, but colorimetry, dark current, integral values etc. Now, Benwin+ 2.0 saves files in binary format, version 1.0 in Ascii format. Export to version 1.0 file to extract required values in ascii format.

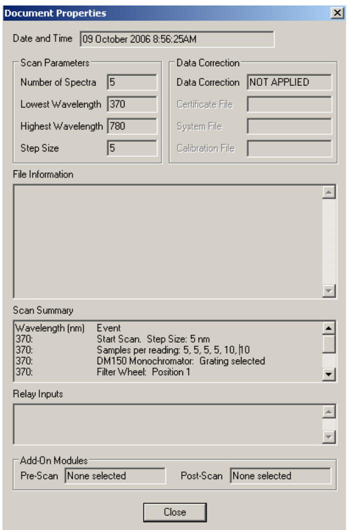
Export to Excel: Export spectral results to Excel.

Graphics File: Export graph in a number of image formats. Having chosen file name and format, the user is then presented with a window to define resolution.

Measurements to ascii*:* Where spectral integrals of an add-on processes further the spectral data, this permits exporting these values to ascii

Copy: Copy spectral values or measurements, (integrals/ add-on values) to paste as text.

Properties: Provides details of spectral measurement, including spectral range, correction factors, file information and summary of scan events.



6.12.2 Scan

Scan setup: See §6.6.3

Signal setup: See §6.6.8

Stationary scan setup: See §6.6.7

Signal monitor: See §6.6.9

Set averaging: short-cut to Instruments/ ADC page See §6.5.1

Scan summary: Provides a summary of actions performed by the system over the defined spectral range in scan setup page.

Data correction: See §6.6.4

Reference setup: See §6.6.6

Add-on modules: See §6.6.11

Auxiliary measurements: See §6.6.12

Set file information: See §6.6.10

Use file information: See §6.6.10

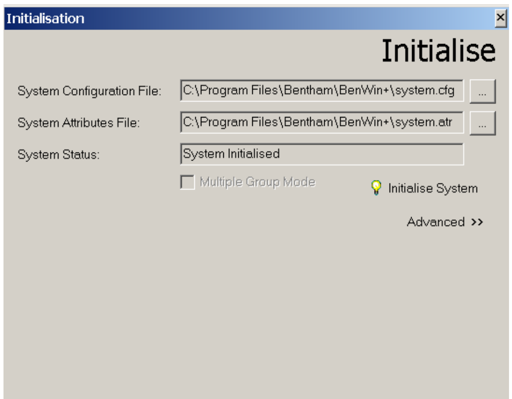
New scan: Initiate new scan in a new scan window, given scan parameters in scan setup page.

Add scan: Initiate new scan given scan parameters in scan setup page, adding scan to active spectrum window.

6.12.3 Tools

Initialise: See §2.3

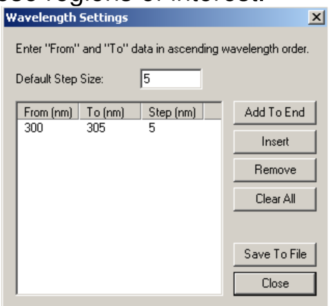
Advanced Initialisation: The standard initialise button establishes communication with hardware based on a default system.cfg file (or the latest *.cfg file used on the computer). The advanced initialisation page permits definition in the first place of a specific *.cfg file to employ.



Here can also be defined instrument group set ups and mode of operation.

It is for example possible to define two groups of detection electronics, operated in ratiometer mode, or a wavelength switched system permitting for example the use of DC electronics in the ultraviolet/ visible spectral regions, and AC electronics in the infra-red.

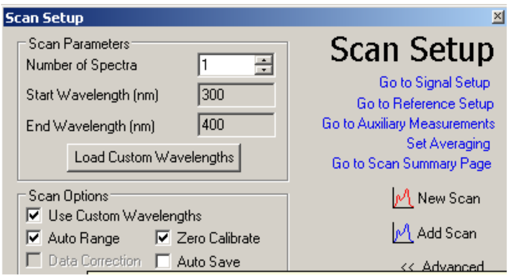
Create custom wavelength file: When measuring for example a line source, rather than performing scans over the entire spectral range, full of barren land, it is possible to define a custom wavelength file limiting scans only to those regions of interest.



One can define a default step size, start and stop ranges, and add, insert or remove as appropriate.

Having defined a custom wavelength file, save.

This file might be implemented going to scan/ scan set up and in advanced>> selecting “use custom wavelengths” and hitting the “load custom wavelengths” button to select the appropriate file.

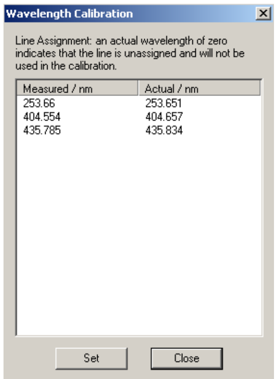


Wavelength calibration: This applies only to DMc150 and M300 monochromators having a stepping motor driven sine- bar mechanism moving the diffraction gratings, and permits ensuring that the device is correctly wavelength calibrated.

A mercury lamp is often used as a standard, although other sources may be used. Please see Appendix 1 for further information.

The procedure follows.

•Acquire a spectrum from the standard source (uncorrected is sufficient)
•Use the peak pick function on the spectrum or add peak markers to the peaks you want to use in the calibration
•Select ***Tools/ Wavelength Calibration/ Set calibration***



This dialog has two columns of peak data, the first column contains the peak data from the peak picked spectrum, the second contains the known peak positions of the source.

The difference between the two is used to calibrate subsequent spectra.

By default, BenWin+ contains calibration data for a mercury emission source. Any actual wavelength values may be modified by highlighting and entering a new value. Setting to zero indicates that the line is unassigned and will not be used in the calibration.

Selecting Set opens a save dialog box and prompts for a filename for the calibration file. Calibration files are of the type *.wlc and by default are stored in ..\BenWin+\Calibration.

These ASCII files contain three columns of data and can be modified by hand. The data stored is measured wavelength, actual wavelength and wavelength difference. It is the difference in wavelength that is used to ensure accurate instrument calibration.

After setting up a calibration file, the default option is to use the file - this is indicated by a tick next to the Use Calibration command in the Wavelength Calibration sub-menu.

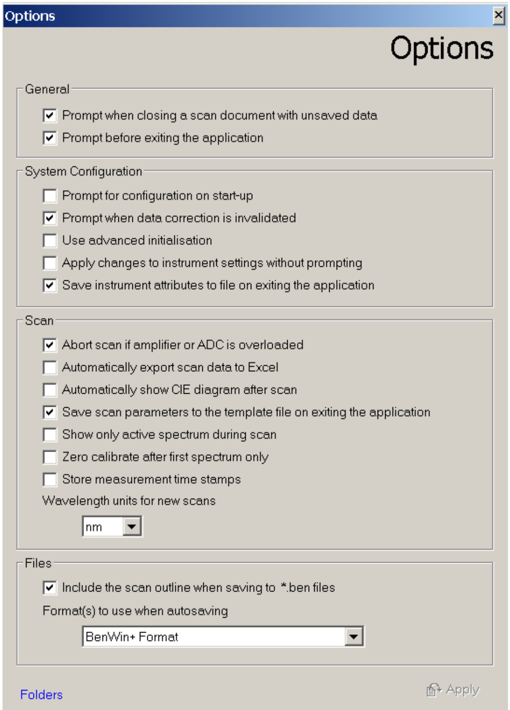
Use Calibration can be toggled on and off by clicking on the command.

A previously saved calibration file can be loaded and used by selecting Load Calibration from the Wavelength Calibration sub-menu.

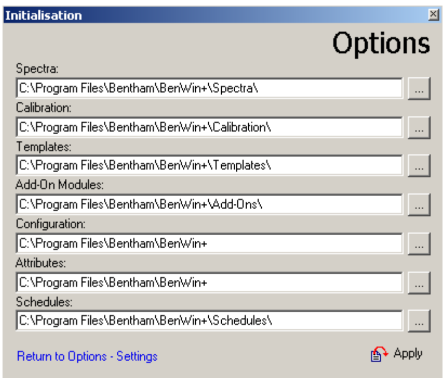
Configure schedule: See §6.6.5

Schedule mode: See §6.6.5

Options: Relates to specific operation options of Benwin+. Certain recommended items are pre-selected.



The default file locations may be modified by following the Folder link bottom left and use the "…" button to navigate to new folder location.



Configurations: See §2.3

Write to log file: Writes to log file for troubleshooting.

6.12.4 Analysis

Set spectrum names: See §6.7.2

Overlay spectra: See §6.7.3

Delete spectra: See §6.7.4

Interpolate: See §6.7.5

Cut: See §6.7.6

Concatenate: See §6.7.7

Invert: See §6.7.8

Normalise: See §6.7.9

Spectral arithmetic: See §7.7.10

Spectral average: See §6.7.3.1

Quantum efficiency: See §6.7.12

Peak picker: See §6.7.13

Select colorimetric data: See §6.8.3

Clear colour regions: See §6.8.4

Set colour regions: See §6.8.4

Update colour regions: See §6.8.4

Set spectral integral: See §6.7.14

Calculate spectral integrals: See §6.7.14

Calculate add-on measurements: See §6.7.11

6.12.5 View

Spectrum: See §6.7

CIE diagram: See §6.8

Spectrograph: See §6.9

Spectral data: Hit this button to present the numerical spectral data to the right of the spectrum window.

Marker list: Shows presently set markers in right hand list.

Measurements: Shows spectral integral results in right hand list.

Vertical split: Position spectral data/ measurements etc window to right of spectrum window.

Horizontal split: Position spectral data/ measurements etc window under spectrum window.

Wavelength colours: §6.7.16

Cursors: See §6.7.15

Markers: §6.7.15

Toolbars: Toolbars are as follows.

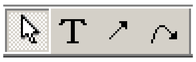
Hardware

Initialise/ Configuration

Main

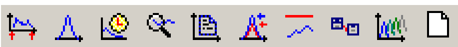
Open/ Save/ Copy spectral data/Print/ Help

Mouse Mode



Cursor/ Add text/ Draw straight arrow/ Draw curved arrow

Scan

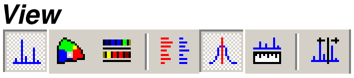


Scan setup/ signal setup/ stationary scan setup/ Signal monitor/ Scan summary/ Data corrections/ Set reference/ Add-on modules/ Set averaging/ New scan

Analysis

Peak picker/ Spectral integrals/ Set spectrum names/Overlay spectra/ Normalise

View



Spectrum view/ CIE diagram/ Spectrograph/ Spectral data/ Marker list/ Measurements/ Cursors

Status bar: Lower screen status bar showing hardware mode, system status, current wavelength and dial reading.

Show auxiliary measurements: where a system is taking auxiliary measurements select to present/ not the auxiliary measurement results (see §6.6.12).

7. Measurement of Spectral Irradiance

7.1 Introduction

The measurement of spectral irradiance involves comparison measurements of a known source (irradiance standard) with an unknown source, using a cosine response input optic, at a given distance.

For the measurement of spectral irradiance, the D7 input optic should be used over the range 200-1100nm (with the DC electronics), and the D8 up to 1700nm with the DC electronics or over the range 1100-3000nm (with the AC electronics).

The D7 should be coupled to the monochromator via the quartz fibre bundle, however in the case of the D8 it is recommended to couple it (via the AC relay optic for AC measurements) directly to the entrance slit, since the quartz fibre has a significant absorption (OH^-) at ~1400nm.

There are two available reference standards, the deuterium CL7 (200-400nm) and the quartz halogen CL6 (250-3000nm).

It is common to use the deuterium source as a relative spectral calibration only, and to use the quartz halogen source to establish the absolute irradiance.

To this end, it is suggested to perform measurements scale the relative calibration factor of the CL7 with the absolute calibration factor of the CL6 at an appropriate point in the overlap region, for example at 350nm.

The scan setup window permits defining a spectrum of constant step size; defining a custom wavelength file permits the use of different steps over the measurement range.

7.2 System calibration

Firstly, one should be aware of the required step size throughout the whole measurement range, where an uneven step is required, a custom wavelength file should be created and used (see §6.12.3).

The measurement procedure is as follows:-

•Set up CL7 irradiance standard, connect anode, cathode and heater and power on
•Lamp shall illuminate in one minute
•Connect the D7 to the DAR of the CL7
•Initialise Benwin+ in DC configuration
•Go to Scan/ Scan setup
•Define start, end and step wavelengths, or load custom wavelength file (or perhaps a truncated version thereof where it is not required to cover the full range with a given calibration lamp)
•Go to advanced, ensure that data correction is NOT selected
•Define number of scans, 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

Repeat the same process where required with the CL6, operating this source at 6.3A with the fan connected.

Note that where custom wavelength files are used, the region of overlap between the two sources should be measured with the same step size, for example 200-400nm in 2nm step with the CL7; 300-1100nm with the CL6, stepping at 2nm up to 400nm and 5nm thereafter.

Where only the CL6 is required for a given spectral range, the following data correction procedure may be applied.

•Go to Scan/ Data correction
•For certificate file load bcf file of lamp
•For system file, select just saved measurement
•Hit calculate calibration data
•On prompt say OK to the application of data correction forthwith
•For future reference, save calibration data

Where a two lamp calibration is performed, please use the procedure indicated in §6.5.13.

7.3 Measurement of sources

From the above, the system is now calibrated in spectral irradiance, permitting the measurement of irradiance of a source at the given distance (that between source and the front of the diffuser).

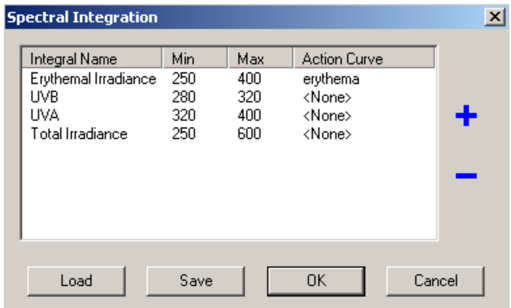
It is important to remember that where the slits are operated in the auto mode that this auto mode is preserved and the step size not changed in any of the regions.

7.4 Results analysis

Having performed a measurement, within Benwin+, further analysis may be carried out.

In Analysis/ Set spectral integrals, one may define integrals, with or without weighting against a specific function.

For example one may define the following:-



In the view menu, one can toggle to the CIE view to determine the colour parameters of a source where this be required.

One may also choose to export the data to Excel for example, running perhaps a macro therein for data analysis.

8. Measurement of Spectral Radiance

8.1 Introduction

The measurement of spectral radiance involves comparison measurements of a known source (radiance standard) with an unknown source, using a telescope as input optic to define the field of view. Radiance is independent of measurement distance.

The TEL309 telescope is coupled directly to the monochromator entrance slit via the telescope FOP-UV.

The reference standard of spectral radiance is the SRS12.

The scan setup window permits defining a spectrum of constant step size; defining a custom wavelength file permits the use of different steps over the measurement range.

In some instances, it may be of concern to ensure that the source presents a uniform irradiance profile on the input lens of the system; where in doubt the entrance can be stopped down.

In reality this consideration is typically only made in measurements with respect to hazard estimation; it should however be noted that to use such reduces the signal level significantly which could present potential measurement difficulties.

8.2 System calibration

The standard measurement of radiance requires that the source overfill the view of the telescope, although as mentioned, this does not apply in the evaluation of the photobiological safery of lamps.

A measurement distance of around one metre is suggested, focussing the telescope on the front of the source, and selecting a suitable aperture that will underfill both the source and the device under test before proceeding.

It should be noted that for a given aperture, as one increases the measurement distance, the area of the source measured increases; on the other hand, the smaller the aperture used, the less signal is transmitted to the monochromator.

The measurement procedure is as follows:-

•Set up SRS12 radiance standard at measurement distance, power on at 8.5A, at
•Let lamp warm up ~10 minutes
•Set up TEL309
•Initialise Benwin+ in DC-radiance configuration
•Go to utilities/ TEL309
•Type in measurement distance, hit apply
•Select correct lens
•Select required field of view
•Go to Scan/ Scan setup
•Define start, end and step wavelengths, or load custom wavelength file
•Go to advanced, ensure that data correction is NOT selected
•Define number of scans, 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
•Go to Scan/ Data correction
•For certificate file load bcf file of lamp
•For system file, select just saved measurement
•Hit calculate calibration data
•On prompt say OK to the application of data correction forthwith
•For future reference, save calibration data

8.3 Measurement of sources

From the above, the system is now calibrated in spectral radiance.

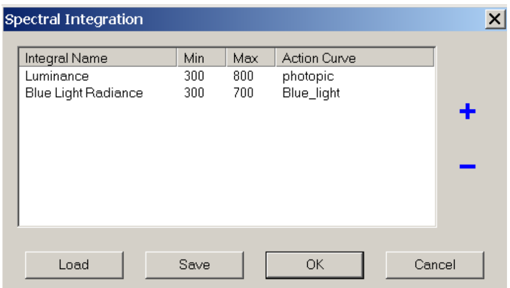
It is important to remember that where the slits are operated in the auto mode that this auto mode is preserved and the step size not changed in any of the regions.

8.4 Results analysis

Having performed a measurement, within Benwin+, further analysis may be carried out.

In Analysis/ Set spectral integrals, one may define integrals, with or without weighting against a specific function.

For example one may define the following:-



In the view menu, one can toggle to the CIE view to determine the colour parameters of a source where this be required.

One may also choose to export the data to Excel for example, running perhaps a macro therein for data analysis.

9. IEC/EN62471:2008- Photobiological Safety of Lamps

This section refers to EN62471:2008 IEC62471:2006, 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.

9.1 Overview

EN62471 provides classification of the photobiological safety of products emitting optical radiation in the range 200-3000nm.

This includes the case of all LEDs except those used for communications, and excludes lasers, covered by EN60825.

Six hazards are considered, relative to exposure to the eye and skin, the quantities to be measured in the determination of hazard, are of irradiance and radiance.

The following table summarises the required measurements.

Hazard	Quantity	Range (nm)
Actinic UV	Irradiance	200-400
UVA hazard	Irradiance	315-400
Blue Light Radiance	Radiance	300-700
Blue Light Small Source	Irradiance	300-700
Retinal Thermal	Radiance	380-1400
Retinal Thermal weak visual	Radiance	780-1400
IR Eye	Irradiance	780-3000
Thermal skin	Irradiance	380-3000

Table 9.1: Measurements required

For each hazard is defined an exposure limit, expressed either as a dose (irradiance radiance times time), or a limit irradiance/ radiance.

IEC/EN62471 classifies sources in four risk groups according to hazard, based on exposure time permissible before hazard exceeded:-

•Exempt- no photobiological hazard

•Group 1- no photobiological hazard under normal behavioural limitations

•Group 2- does not pose a hazard due to aversion response to bright light or thermal discomfort

•Group 3- Hazardous even for momentary exposure

Risk group classification of a source is according to a specific class is based on permissible time of exposure with no hazard- no hazard present within a given time of exposure.

In the case of spectral irradiance, the hazard limit is simply divided by the measured irradiance to determine the exposure time, which is then compared with the permissible exposure times of the various risk groups.

In the case of radiance, the measurement geometry (field of view of measurement) is, *per se,* based on time.

It is not possible simply to measure that radiance in a manner analogous to the measurement of irradiance and determine the permissible exposure time since the field of view of measurement is dependant on time of exposure.

It is therefore of question to evaluate the source radiance with a field of view corresponding to the minimum exposure time of a given classification to determine if the source passes or not the criteria of the stated class.

9.2 Measurements with IDR300

All measurements are to be performed with the IDR300 with the appropriate input optic, calibration standard and detection electronics.

It should be also noted that the standard recommends instrument bandwidth per wavelength region. It is recommended to perform measurements at a step size equal to the bandwidth.

Range (nm)	Bandwidth (nm)
200-400	<4
400-600	<8
600-1400	<20
>1400	No limitation

Table 9.2:EN62471 Recommended instrument bandwidth

The IDR300, operating in auto slit mode will set the instrument's bandwidth to the scan step size; custom wavelength files may therefore be created, changing step size as required over the range of measurement.

To produce standard measurement conditions, it is recommended to define standard measurement criteria to be applied to both measurements of irradiance and radiance where practical, for example:-

Range (nm)	Step size (nm)
200-400	2
400-1100	5
1100-3000	10/20

Table 9.3: Recommended step over range

It should of course be remembered that the slit width has an impact upon the throughput and therefore sensitivity of the system. This may potentially be of particular importance in the lower-throughput measurements such as that of irradiance, and radiance in small fields of view.

Indeed, the system limitations in both irradiance and radiance can be characterised by performing measurements in the dark and evaluating the results of all hazards to determine the noise floor, termed the noise equivalent irradiance/ radiance (NEI/ NER).

9.3 Irradiance Measurements

According to the standard, spectral irradiance should be measured with a cosine response input optic, with input no smaller than 7mm and no larger than 50mm.

In the measurement of non-uniform sources, to perform the measurement with a smaller aperture may lead to the measurement of higher peak irradiances; to use a larger aperture could represent an overly large averaging aperture, potentially underestimating the irradiance.

This system is accompanied by two input optics, the D7 and the D8.

The D7 is useable over the spectral range 200-1100nm and has better cosine response than the D8 integrating sphere-based diffuser useable over the range 200-3000nm.

The cosine response of the D8 deteriorates at the wider angles; for sources measured at such a distance that they may be considered point sources, it is suggested that the poorer cosine response has no impact upon measurements.

In this manner, measurements can be performed over the spectral range 200-1700nm with the D8 optic, and the DC electronics

Spectral irradiance being dependant on distance, the measurement of irradiance should be performed at:-

•For general lighting service (GLS) lamps, used to illuminate spaces, the distance at which the source irradiance is 500lux should be used as the measurement distance, and should not be less than 200mm

•For all other sources, the measurement distance is 200mm

Furthermore, the standard states that measurements of irradiance need only be performed over a 1.4 radian (80°) view, and that where sources subtend a larger angle than this, they should be suitably apertured close to the source.

Firstly, one should note that the measurement of the 500lux measurement distance is performed with the full hemisphere view, and as such increases the measurement distance compared with doing the same at 1.4radian limited view.

Secondly, in practice, to prepare a large number of such apertures, of dimension sufficiently large to cover the source, and of a wide range of diameters may not be practical.

It is suggested in the first instance to perform measurements of the entire source, ignoring apertures, and considering the classification.

Where a device is exempt, then having reduced the signal with apertures would have no effect. In all other cases, where they arise, recourse can be had to the use of apertures.

In practice, one need not use such an aperture in the first instance, measuring the full view which would therefore over-estimate the error. Should the device fail a particular class, the measurement may be repeated with the aperture required to ensure that this be not the cause of failing.

This same technique shall be further described in the evaluation of the exempt classification of the blue light radiance, measured in a 100mrad field of view, which angle is impractical for measurement via a telescope; the measurement shall therefore be performed as one of irradiance in a defined field of view, apertures therefore being applied where required.

9.4 Radiance

In terms of EN62471, the radiance to be measured is more correctly termed a physiological radiance; it differs from the strict definition of radiance in that, a field of view may subtend an angle larger than the source, what is measured is therefore an average radiance.

For a given field of view, however, as the measurement distance is reduced, less of the source is measured and vice versa; all measurements should be therefore performed at the required measurement distance, 500 lux distance or 200mm.

The measurement field of view corresponds to the image formed on the retina by the eye, and, increases with time according to the following rationale.

Due to physical limitations of the eye, the smallest image that can be formed on the retina is limited to a minimum value, in this standard, taken as 1.7mrad.

This measurement field of view corresponds to exposure less than the blink reflex time, 0.25s

For times greater than 0.25s, rapid eye movements smear out the image of the source over increasingly larger angles, and this up to 100s exposure.

Greater than 100s exposure, the irradiated area shall further increase die to task determined eye movements, up to a maximum angle of 100mrad.

Exposure Time (s)	Field of View (mrad)
<0.25	1.7
0.25-10	$11\sqrt{(t/10)}$
10-100	11
100-10000	$11\sqrt{t}$
>10000	100

Table 9.4: Variation of field of view on time

In practice, the variation of the field of view with time should be largely ignored since the position to be adopted is not one of determining the exposure time, but one of evaluating the source at the exposure times relating to the different classes, as shown below.

Hazard	Maximum permissible exposure time (s)		
	Exempt	Group 1	Group 2
Blue Light Radiance	10000	100	0.25
Retinal Thermal	10	10	0.25
Retinal Thermal weak visual	1000	100	10

Table 9.5: Exposure time limits per class

For example, performing a measurement at the field of view corresponding to the 10000s exempt class limit of exposure to blue light, one measures a source radiance over 100mrad.

Based on the maximum dose, the permissible exposure time to this measured radiance should be calculated. If this exposure time is greater than the maximum exposure time of the class, then the device belongs to the said class, otherwise it should be evaluated at the FOV corresponding to the next class.

As described in §3.2.2, radiance can be measured by one of two techniques, by an imaging method, or as an irradiance in defined field of view (dividing the measured irradiance by the solid angle corresponding to the measurement field of view to obtain radiance).

With reference to tables 9.4 and 9.5, one can see that the important FOVs of measurement are 1.7, 11 and 100mrad.

The first two fields of view are easily obtainable with a telescope-based imaging technique, however the 100mrad is rather too large a field of view, and for this reason, it is suggested that this latter quantity be measured as a radiance by irradiance.

It should be noted that the measurement is of the maximum signal obtained within a field of view; if in the 100mrad case, several component LEDs fall into the view, whilst at the 11mrad field of view only one device is seen, this is correct.

9.5 Source Location and Angular Subtense

Knowledge of the source location is required for all measurements of non-GLS sources; knowledge of source angular subtense is required in the evaluation of the retinal thermal hazards (since it describes the size of the irradiated area of the retina).

Furthermore, for sources subtending less than 11mrad, the blue light hazard analysis can be simplified to a measurement of spectral irradiance.

Using a lens of known focal length, the source should be imaged on a screen at distance s2 from the lens. From the lens equation, s1, the distance from the lens to the apparent source may be determined by 1/f = 1/s1 + 1/s2.

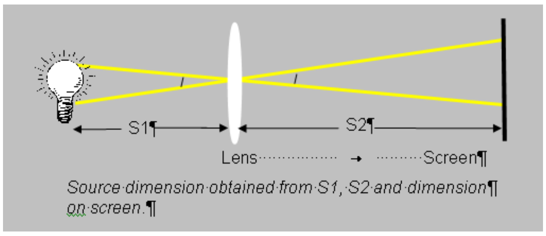
The angular subtense is determined from knowledge of the source dimensions and the measurement distance, in this case 200mm.

The source dimensions, here of the illuminator LED, is determined by imaging the source onto a screen with a lens, and measuring S1, S2 and the dimensions of the image on the screen.

This permits the determination of the source size, which, coupled with the measurement distance yields the source subtense.

Figure 9.1: Source subtense and location determination

9.6 Measurement Preamble

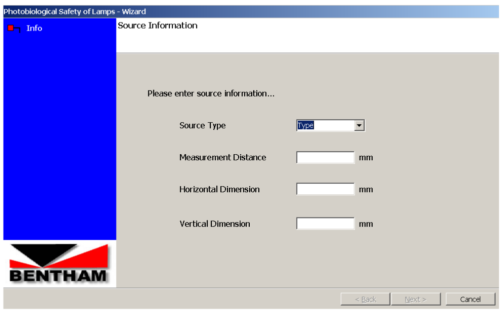


Given a source for measurement, it is recommended to perform a spectral check measurement over the maximum range of the system to get an idea of the spectral output of the source.

To measure the source effectively with a bare fibre over the range 200-1700nm, with the source at five times the largest dimension no less than 200mm from the diffuser will in many cases use the full dynamic range of the system without saturating the detector. Note that with no data correction applied, the y-axis of the scan reports nA, where ~90000nA is the maximum photocurrent.

9.7 PSL Wizard

The photobiological safety of lamps wizard guides the user through the convoluted measurement procedure in the classification of devices against either IEC62471:2006, EN62471:2008 or the EU artificial optical radiation directive, an overview of which is seen on the next page.



Having defined the source nature and input the geometrical information, one is guided through the relevant measurements and conditions.

Classification and labelling information is also provided
.

10.1 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 setting up the various configurations.

10.2 Measurement Distance

The measurement distance to be applied depends on the application of a particular source; sources being classified as either GLS or non-GLS.

GLS “general lighting service” sources are those used to illuminate spaces “uniformly”. This does not include for example torches, nor does it include, in the opinion of the author, directional sources. GLS sources are measured at a distance at which they produce an Illuminance of 500 lux.

Non-GLS sources include specialist lamps, UV lamps, IR lamps, coloured LEDs etc. the measurement distance in which case is 200mm, which corresponds to the near point of the human eye.

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.

The GLS 500lx distance may be measured with respect to a chosen reference point on the source. The non-GLS 200mm measurement distance, relating to the imaging of the eye, should be relative to the location of the source of light; where lenses are employed, the location may not be the same as the physical source location.

10.3 Determination of 500 lux distance

The IDR300-PSL lux meter should be mounted on the optical rail. The meter software should be run from Benwin+/ utilities/ meter. This requires that one of the configurations be initialised.

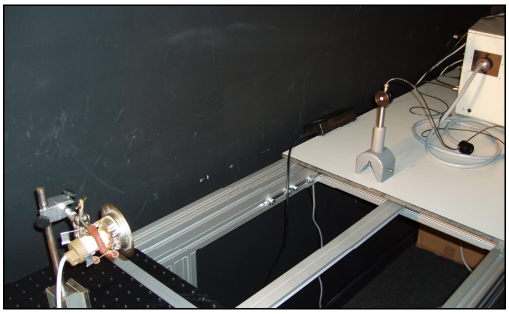


Figure 10.1: Determination of 500lx distance

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. 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.

10.4 (Apparent) Source Size and Location

In the case of specialist lamps, it is necessary to determine the apparent source location; for all sources, it is necessary to determine the source size to permit evaluation of the retinal thermal hazard and to determine if a source may be treated as a small source for consideration of the blue light hazard.

The apparent source location is the location of the source that the eye images. Where lenses are used to control the source output, the source location may not be in the same position as the physical source, as can be seen in the following example, where the use of a lens to control the output of an LED creates a magnified image of the source behind the physical source location- it is this latter that the eye images is not the physical LED but the magnified image of the source.

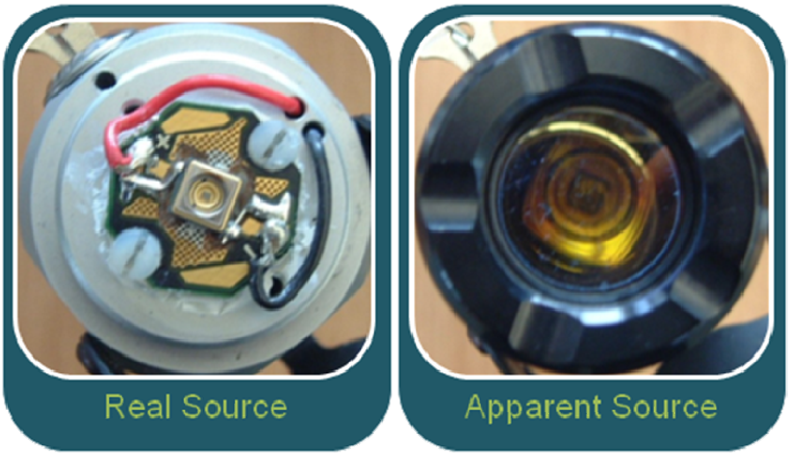


Figure 10.2&3: Real and apparent sources

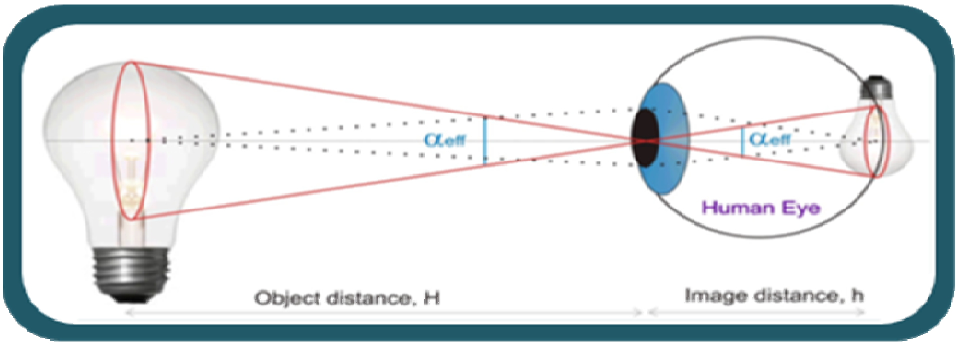


Figure 10.4: Imaging of the eye

The source angular subtense is the full angle, α_{eff}, subtended by the source at the measurement distance, and can be estimated by the ratio d/D, where d is the source size and D the measurement distance.

In principle, the size of the source, d, is defined by the 50% light emission points.

For a bare source, the measurement distance can be taken from the front most 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. The source dimension can be measured directly at the source in two orthogonal directions, horizontal and vertical or whatever is appropriate to characterise the size of the source.

For all other sources, an imaging technique should be used. The Bentham PSL profiler is still in development, the only advice to be given presently is to use a suitable lens of known focal length to image the source onto a screen.

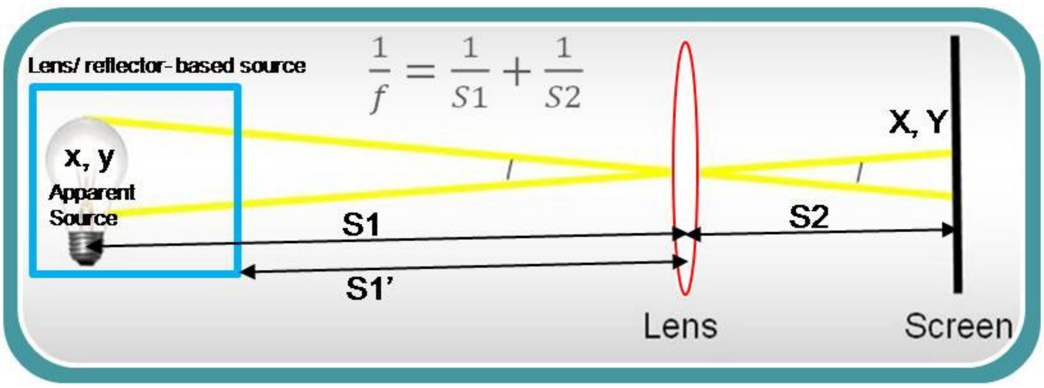


Figure 10.5: Determination of source angular subtense

The lens is placed at distance S1 from the source, the distance S2 being that between the lens and the screen.

For a fixed source and screen position, there are two positions in which an image will be created (two conjugates); where S2>S1, a magnified image is formed, and where S1>S2 a demagnified image is formed. It is the magnified image that we seek.

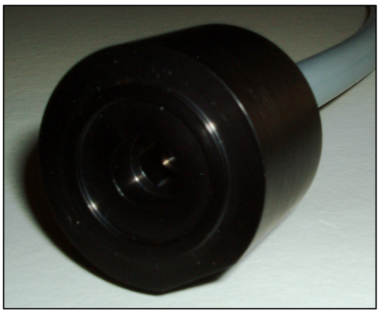
Measure S2, the x and y dimensions on the screen and measure S1', the distance between the lens and a reference position on the source.

Using the above formula, given f, the focal length of the lens and S2, one can determine S1. It should of course be realised that this procedure is subject to a degree of uncertainty of at least 5%.

Now, S2/S1 is the magnification of the system; dividing x and y by the magnification permits determination of the true source dimensions.

10.5 Spectral Check Measurement

The spectral check measurement uses the full range of the IDR300-PSL DC configuration to determine via a high throughput measurement where there is light emission.



10.5.1Hardware Setup

•IDR300-PSL with PMT, Si, InGaAs
•FOP-UV with spectral check input optic
•CL6-H calibration lamp with 605 supply

10.5.2 Software Setup

• Initialise Benwin+ in the spectral check configuration

10.5.3 Calibration Measurement

•Set up CL6 irradiance standard, connect red and black cables and fan
•Ensure current of 605 set to 6.3A, power on, allowing 5 minutes warm-up period
•Connect the 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 (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

10.5.4 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

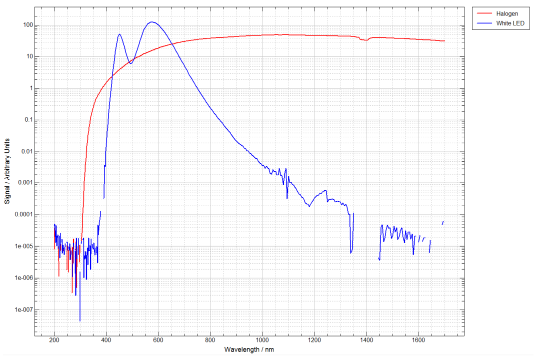
10.5.5 Source Measurements

•Position source at 200mm from input optic, correctly aligned
•If in doubt, perform alignment by monitoring the signal level with the alignment utility
•Hit new scan and save file

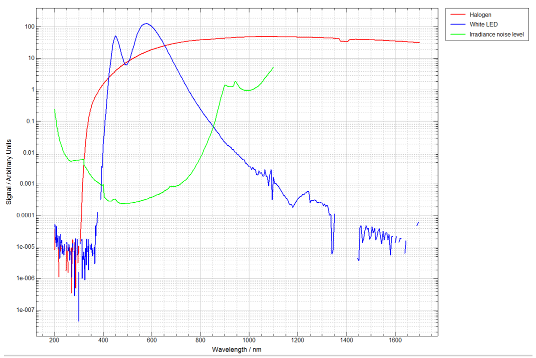
10.5.6 Interpretation of Results

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.



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.



It is intended that this analysis forms part of the PSL calculation software in a future release.

10.5.7 Alignment Utility

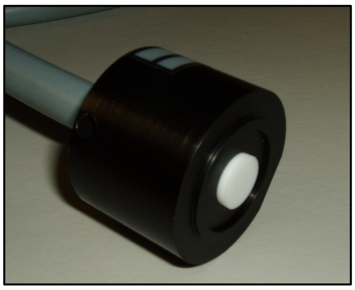
•Go to scan/ signal setup
•In target wavelength field, type wavelength at which source expected to emit, for white light sources recommend 555nm (peak of eye response)
•Hit go to target wavelength
•Close signal setup page
•Go to utilities/ alignment
•Shall be presented on the screen the measured photocurrent
•Adjust source position to obtain maximum value

10.6 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.

10.6.1 Hardware Setup

•IDR300-PSL with PMT, Si, InGaAs
•FOP-UV with D7 cosine corrected input optic
•CL6-H calibration lamp with 605 supply
•Where measurements in the UV are required, CL7 calibration lamp with 705 power supply



10.6.2 Software Setup

• Initialise Benwin+ in the irradiance configuration

10.6.3 Calibration Measurement

•Set up CL6 irradiance standard, connect red and black cables and fan
•Ensure current of 605 set to 6.3A, power on, allowing 5 minutes warm-up period
•Connect the D7 diffuser to the quartz fibre bundle
•Connect the D7 to the CL6
•Go to Scan/ Scan setup, (scan range should be defined 300 to 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
•At the end of the scan, save, giving appropriate name
•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, 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

10.6.4 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
•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:-

•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

10.6.5 Source Measurements
•Perform measurements as prompted by the PSL wizard
•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
•Where an aperture is required to limit the output of the source to 100 mrad with regards the blue light exempt hazard, since this applies a pass/ fail criteria, the user may choose to try to evaluate with no aperture in place to save time, since if the source passes with no aperture in place it will certainly pass with an aperture in place
•Where the placement of an aperture is difficult, it is possible to apply a scale factor to account for the reduced area of measurement
•The user may decide to keep in place the same custom wavelength file or to use other custom wavelength files appropriate to the measurement required, for example UV 200-400nm, blue light 300-700nm etc. In any case, the same step size profile as that used at calibration should be maintained
•Position source at correct measurement distance, 500lx of 200mm from apparent source and correctly aligned
•Perform alignment via monitored signal level
•Save file

10.6.6 Interpretation of Results
The results of these measurements may be passed to the PSL wizard to perform calculations.

The user may also view the automatically calculated values to the right of the spectrum and calculate either by hand or using the PSL wizard manual excel file the exposure times and classifications.

10.7 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.

10.7.1 Hardware Setup
•IDR300-PSL with PMT, Si, InGaAs
•TEL309 with quartz fibre bundle
•SRS12 calibration lamp with 605 supply

10.7.2 Software Setup
• Initialise Benwin+ in the radiance configuration

10.7.3 Calibration Measurement
•Position SRS12 at sample plane, central to TEL309
•Set up SRS12 radiance standard, connect red and black cables
•Ensure current of 605 set to 8.5A, power on, allowing 5 minutes warm-up period
•Go to utilities/ TEL309
•Input measurement distance, apply
•Ensure telescope in focus- of use is to place a piece of paper with text at the output of the SRS12 to ensure in focus and central
•In the TEL309 window, select 11mrad
•Go to Scan/ Scan setup, (scan range should be defined 300 to 1400nm, if not go to advanced, check use custom wavelength file, and load radiance)
•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
•Go to utilities/ TEL309
•In the TEL309 window, select 1.7mrad
•Repeat measurement, saving at end of scan
•Power off SRS12 and allow one minute cool-down time prior to moving lamp

10.7.4 Applying Calibration
•In turn calculate correction factors for 11mrad and 1.7mrad in data correction
•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

10.7.5 Source Measurements
•Go to utilities/ TEL309
•In the TEL309 window, select 11mrad
•Position source at measurement plane
•To aid alignment, set target wavelength to 555nm
•Hit go to wavelength
•Optimise source position for maximum signal
•Close TEL309 and perform new scan
•Save result
•Pass result to PSL-Wizard
•Where required repeat measurement in 1.7mrad FOV
•Go to utilities/ TEL309
•In the TEL309 window, select 1.7mrad
•To aid alignment, set target wavelength to 555nm
•Hit go to wavelength
•Optimise source position for maximum signal
•Close TEL309 and perform new scan
•Save result

10.7.6 Interpretation of Results
The results of these measurements may be passed to the PSL wizard to perform calculations.

10.8 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.

10.8.1 Hardware Setup
•IDR300-PSL with PbS detector AC electronics, relay optic and chopper, and Benwin+ AC configuration.
•CL6 calibration lamp with 605 supply

10.8.2 Software Setup
•Initialise Benwin+ in the infrared configuration

10.8.3 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 605 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

10.8.4 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

10.8.5 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

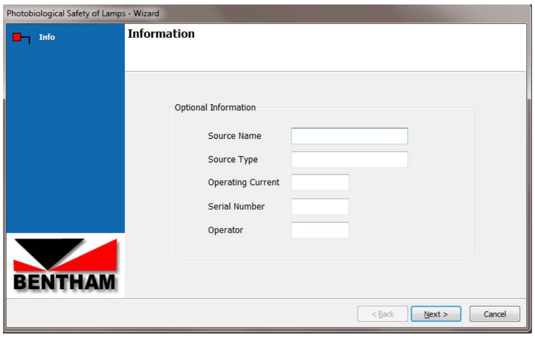
10.8.6 Interpretation of Results

The results of these measurements may be passed to the PSL wizard to perform calculations.

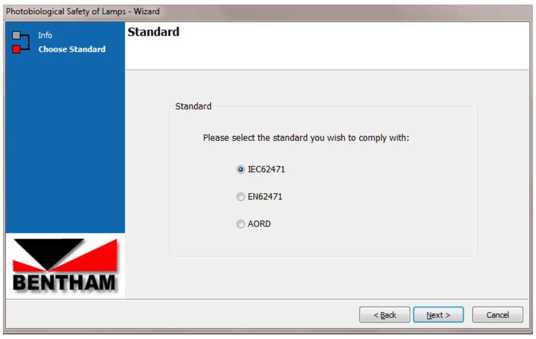
10.9 PSL Wizard

The PSL wizard can be accessed from the utilities menu. This add-on guides the user through the measurements required, prompting for information as required and culminating in a measurement report.

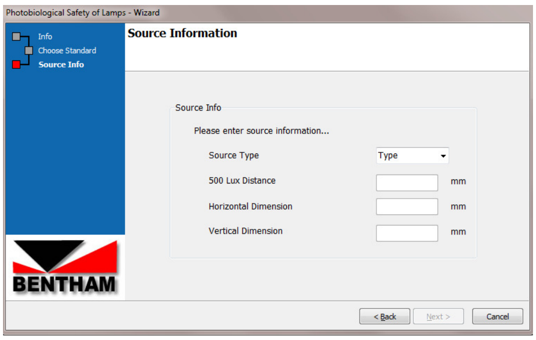
•Input lamp identification information



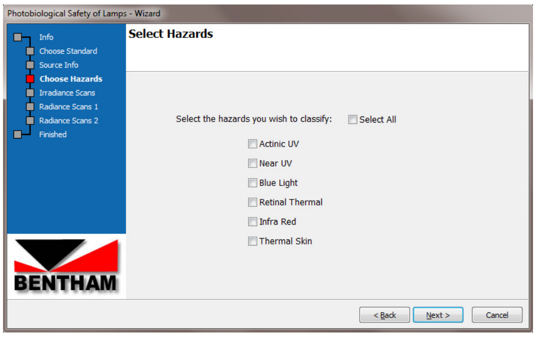
•Select which standard to apply. IEC62471 and EN62471 differs only in the limit of the exempt risk group for blue light small source. The AORD analysis permits measurement of irradiance at zero exposure distance



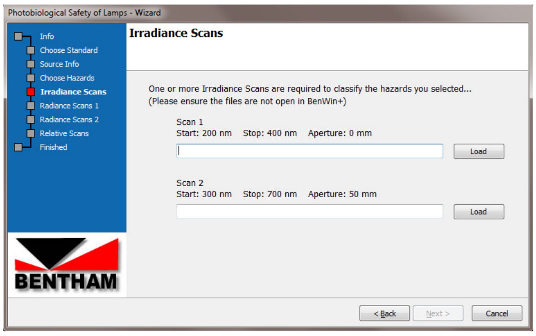
•Define source type, measurement distance and source size



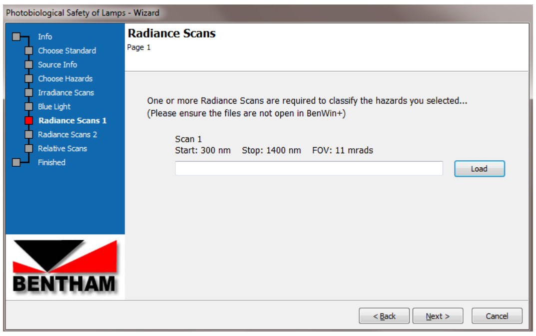
•Select hazards to consider, based on conclusions of spectral check measurement



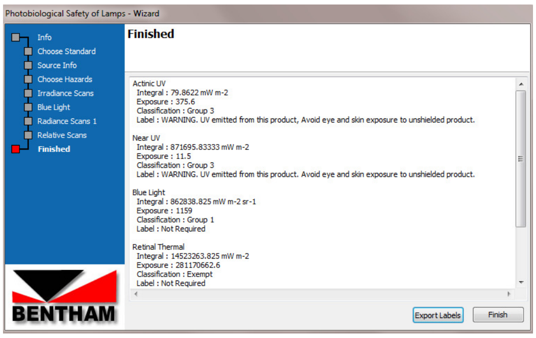
•The user will be prompted to perform measurements as required, given wavelength range, and aperture for irradiance and field of view for radiance



•Where blue light is considered, should the device fail the exempt group, recourse must be made to measurements of radiance



•The results are then reported, with the option of exporting to a word report template



•The word template produces a customisable report such as the following

Serial Number	12345
Source Type	UV source
Operating Current	350mA
Operator	Anon
Dimensions	50 x 50 mm
Measurement Distance	200 mm

IEC62471 Evaluation

Measured at 200 mm from apparent source

Measured Value	Time to Exposure Limit (s)	Limi
7.99E+01	3.76E+02	1.00E
8.72E+05	1.15E+01	1.00E
8.63E+05	1.16E+03	1.00E
1.45E+07	2.81E+08	2.81E

Overview of IEC62471 classification

Hazard	Risk Group
Actinic UV	**Group 3**
Near UV	**Group 3**
Blue Light	**Group 1**
Retinal Thermal	**Exempt**

Labelling

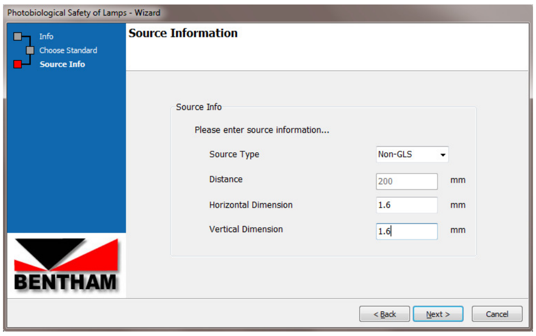
WARNING. UV emitted from this pro
WARNING. UV emitted from this pro

10.10 Example Analysis
A surgical illuminator is provided for measurement, consisting of a single PC-white LED

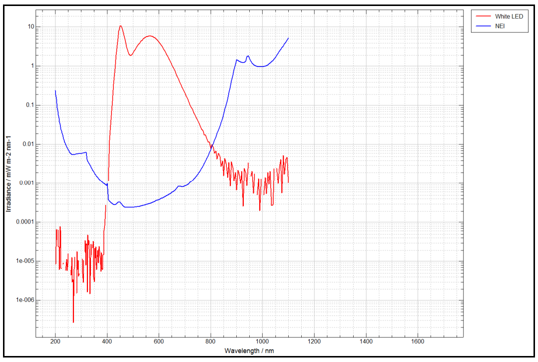
10.10.1 Measurement Distance
•Non-GLS source
•Measurement distance 200mm

10.10.2 (Apparent) Source Location and subtense
•Image LED onto screen with lens (focal length 100mm)
•Source reference point-lens distance= 108mm
•Lens image distance= 572mm
•x-dimension image= 8.5mm
•y-dimension image= 8.5mm

=>Calculate source- lens distance = 121mm
=>Source x, y size = 8.5x121/572 ~ 1.6mm
=>Source subtense x,y at 200mm ~ 1.6/20 ~8mrad
=> Blue light small source

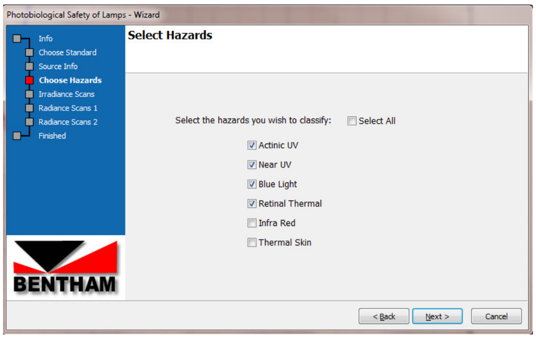


10.10.3 Spectral Check
Using the spectral check configuration and input optic, the source relative output was measured 200-1700nm, indicating that significant emission exists only in the region 400-800nm, zero signal being recorded in the IR.



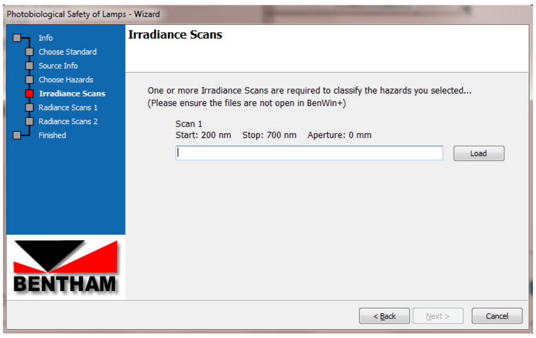
Since this is not an IR source, one can presume that there be no further IR emission above 1700nm.

Since one has to measure 300-700nm for the blue light hazard, it is recommended to evaluate also the UV hazard based on the same measurement.

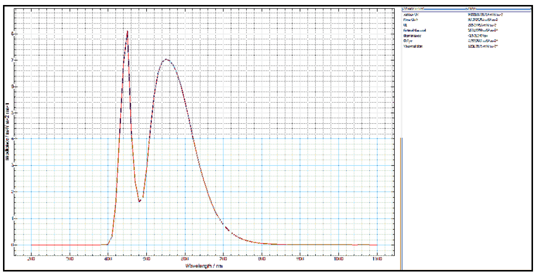


10.10.4 Spectral Irradiance 300-1100nm
Using the irradiance configuration and D7 input optic, the source spectral irradiance is determined at the correct measurement distance over the range 300-1100nm.

Since this is a small source no apertures are required in the measurement of irradiance.

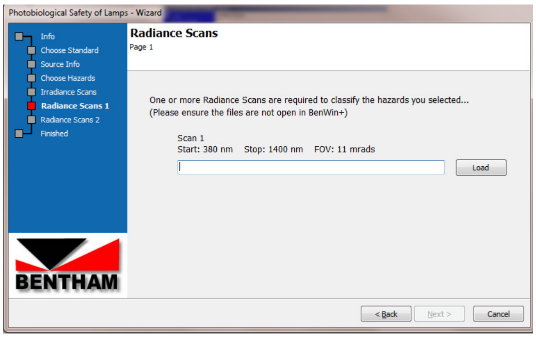


•Whilst wizard prompts 200-700nm, based on spectral check, limit measurement to 300-700nm
•Measure, save and close file
•Load file into wizard
•Since blue light small source being here evaluated, we have no further treatment of blue light hazard

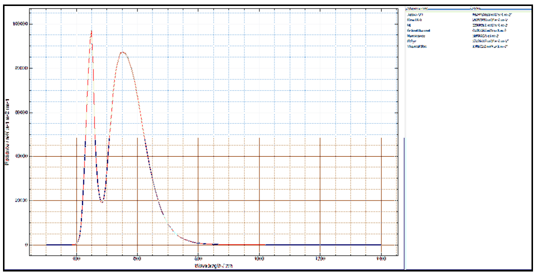


10.10.5 Spectral Radiance 380-1400nm

Using the radiance configuration and TEL309 input optic, the source spectral radiance is determined in the range 380-1400nm.



•Measure radiance 380-1400nm in 11mrad FOV
•Save and close file
•Load result in PSL Wizard
•Having loaded file, wizards moves directly to relative IR scan, therefore 1.7mrad measurement not required (passed group 1 for retinal thermal)



10.10.6 Reporting Results

Based on measurement results provided, the wizard returns the calculations and labelling information required as per IEC62471-2. The overall risk group of the device is the worst case result.

11. Precautions

11.1 Precautions

This section deals in the first instance with those precautions that should be observed in using this system, then with the cases where something goes wrong

The following is a list of specific precautions aimed to preserve for good use this system.

Calibration standards
•Ensure correct bias applied and fan connected at all times
•When lamp warm do not subject to physical shock to prevent damage to the filament

Monochromator
•Do not touch gratings nor optics
•Do not subject monochromator to violent physical shock- this may invalidate wavelength calibration

Fibre bundle
•Ensure bend radius never less than 100mm

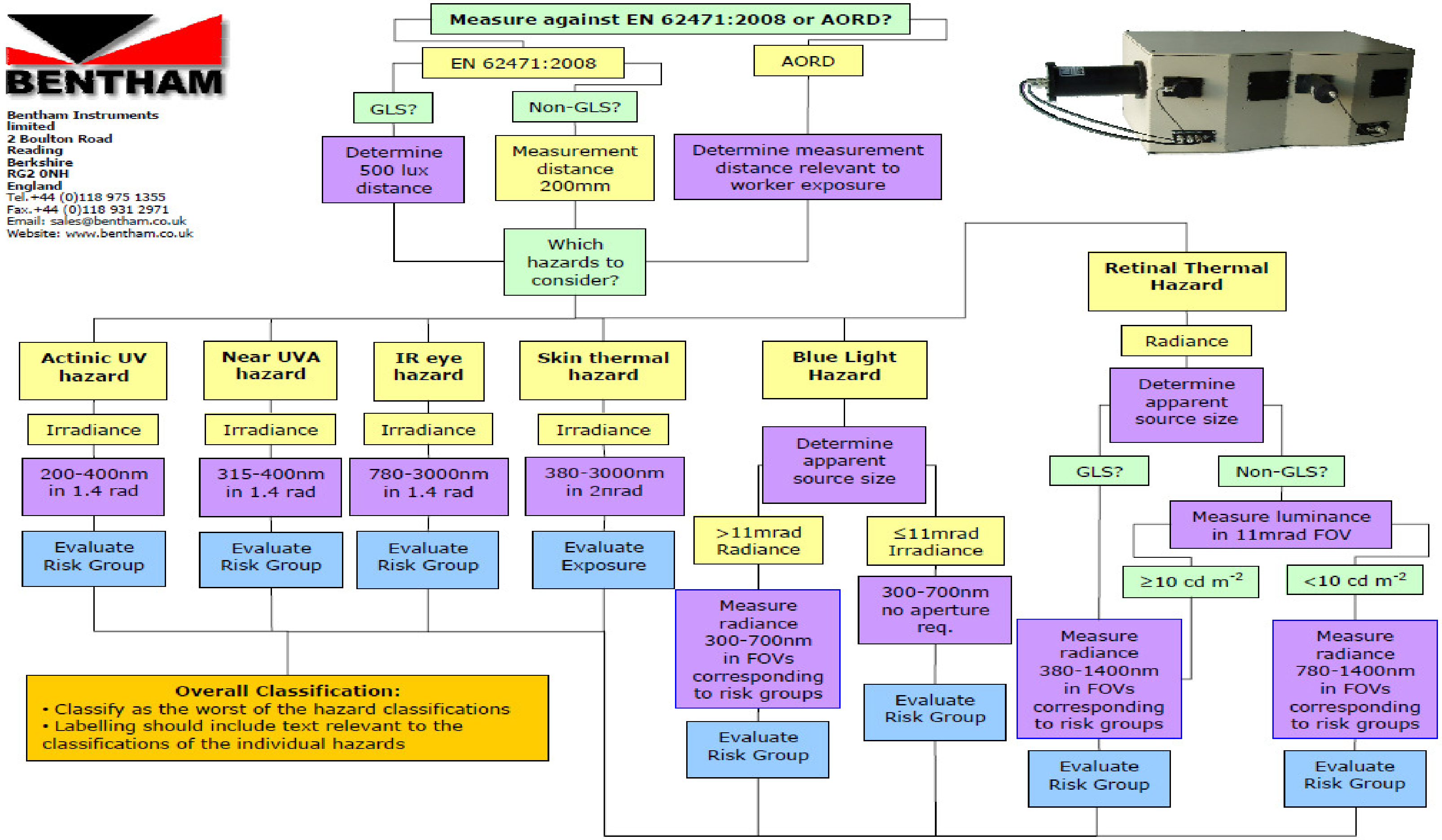


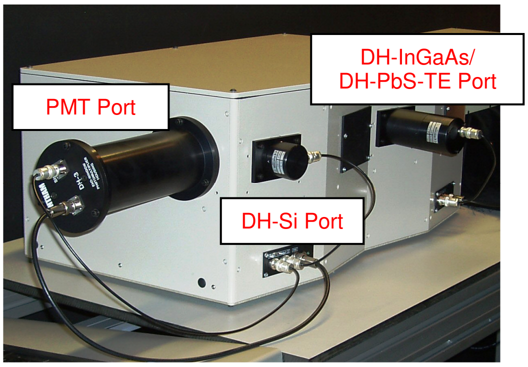
Figure 10.6: EN62471:2008 measurement overview

Appendix 1: System Installation

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

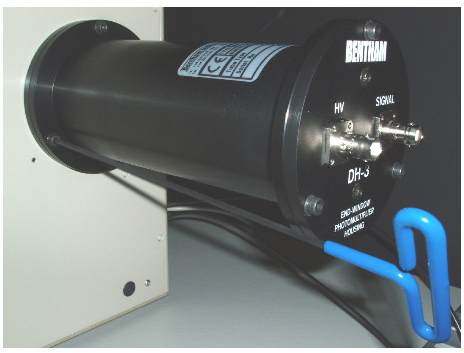
Monochromator
The monochromator should be sited in a suitable location. Only handle the IDR300 from the base of the unit- never use connected detectors as handles. When mounting detectors and the input optic to the IDR300, ensure that the correct length of screw is used. This ensures no damage to the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

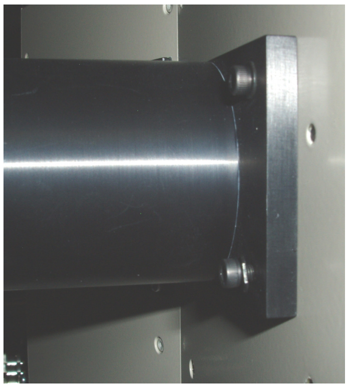
The DH-3 is adapted to the exit slit via an adaptor fitted to the slit.



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 luxmeter 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.

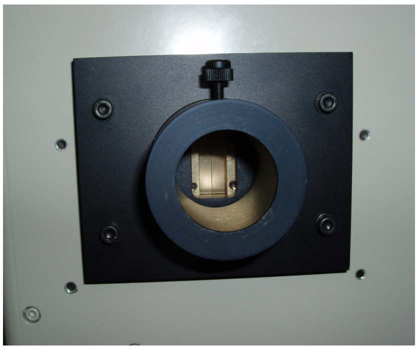
DH-InGaAs: Detector connected to IDR300 input 3 using thin BNC cable.

Luxmeter: Detector connected to IDR300 luxmeter input.

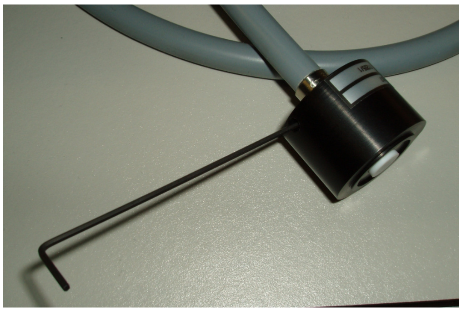
Quartz Fibre Bundles
Both quartz fibre bundles are made such that on the input optic side they have a round ferrule and the monochromator side a rectangular ferrule to fit as closely as possible to the motorised slit.

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.



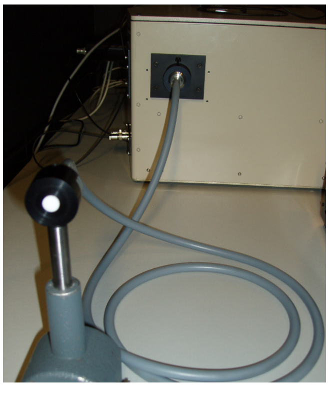
D7 Cosine Diffuser Input Optic
The D7 input optic permits the measurement of absolute irradiance; the spectral check input optic is based on the body of the D7, but having no PTFE insert is used only as a high throughput manner of measuring the relative spectral output of sources.

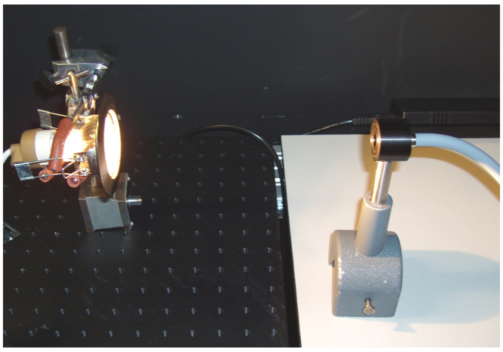


On the side of the spectral check and the D7 diffuser input optics, the quartz fibre bundle ferrule is pushed inside the body of the optic and held in place with a grub screw. Both optics have an M6 threaded hole to one side for mounting on a post.

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.

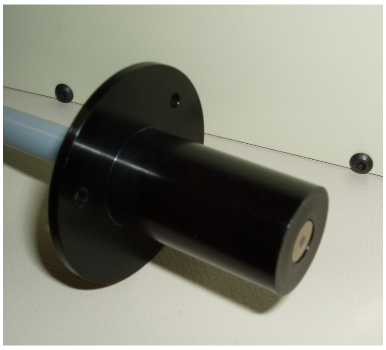




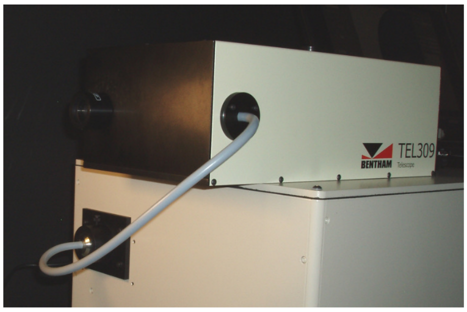
TEL309 Telescope
It is recommended to install the TEL309 on top of the IDR300 due to the short fibre in use.

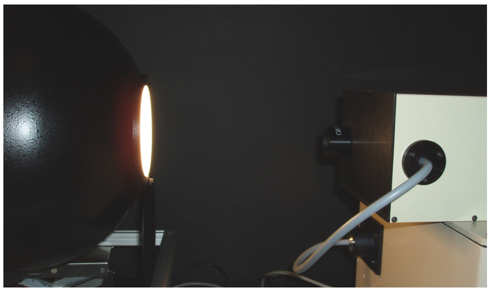
The TEL309 requires a mains power and USB connection. Please follow instructions in the section on software for installation of the USB camera drivers.

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.



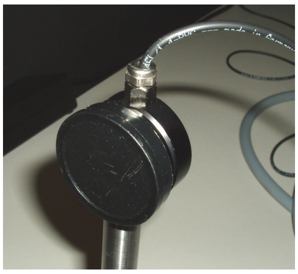
In use, the measurement distance used is the one between the entrance lens of the TEL309 and the source under consideration.



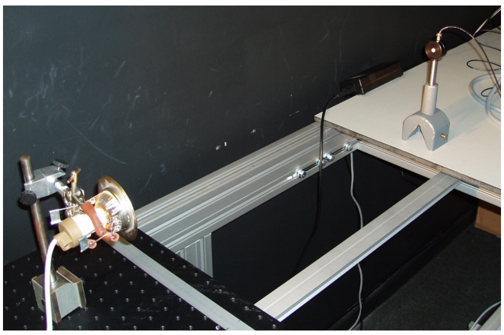


Luxmeter
The luxmeter is used to determine the 500lux measurement distance of GLS sources.

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.

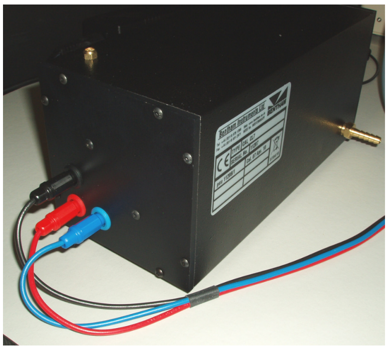


In use, with the correct alignment, the measurement distance is varied to obtain 500 lux, and the measurement distance recorded from the front surface of the luxmeter to the reference point on the source.



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

The deuterium standard of irradiance is operated by the 705 power supply.



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

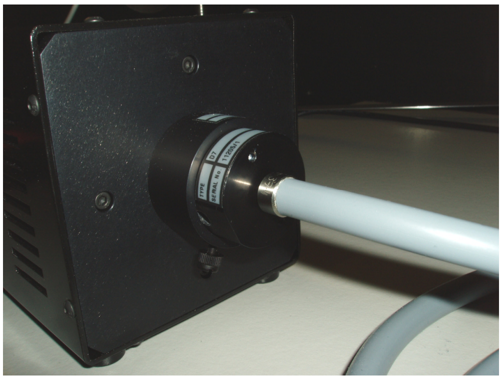
The CL6-H is a quartz halogen standard of spectral irradiance, operated by the 605 constant current supply at 6.3A.

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 605 for reference.

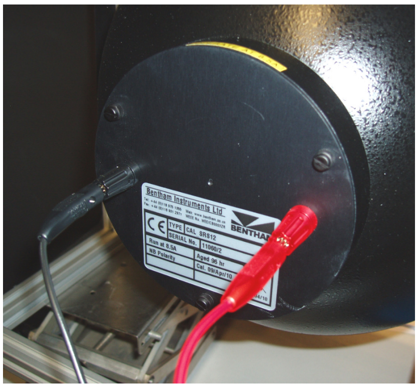
In use, the irradiance calibration of both the CL7 and CL6 are provided at 5.5mm from the front face, a distance set by the DAR adaptor screwed into the front of the source.

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 605 constant current supply at 8.5A.

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

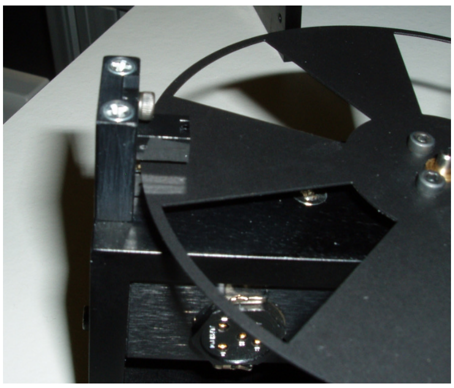


In use, the output port of the SRS12 is used as a uniform standard of radiance; one images therefore the plane of the port of the SRS12 in measurements, the measurement distance is from the lens of the TEL309 to the plane of the port.

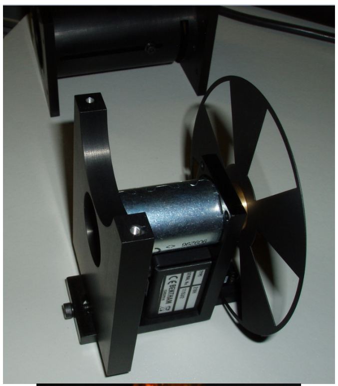
AC Measurement Setup
Measurements in the infrared require a different input optic and the use of the DH-PbS-TE detector.

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.

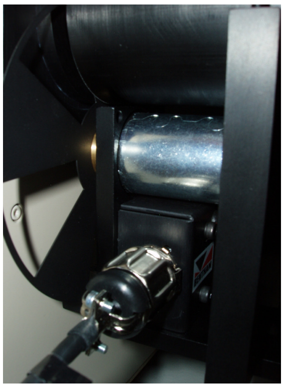


The DH-InGaAs detector should be removed and replaced with the DH-PbS-TE.

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:-

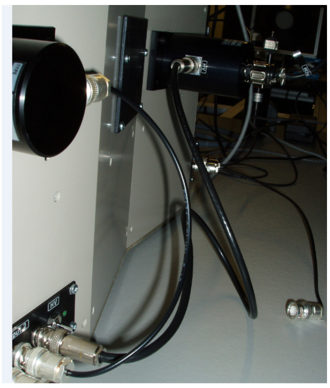
-Connect 218 choper controller to chopper using 5 pin cable



-Connect CPS1M to detector rear port using 5-pin connector

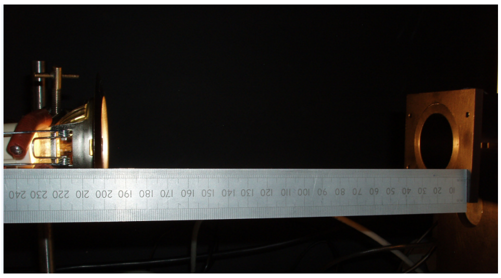
-Remove HV cable from PMT and attach to PbS detector HV port

-Connect detector signal port to input 1 of 477 amplfier



Ensure chopper and CPS1M both powered on.

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.



For information only, to check the phasing of the lock-in amplifier, to be used in conjunction with §6.5.8, with a light source in place, use signal setup to select a wavelength where there is light and the system responds, and hit go to wavelength (for example 1000nm with the CL6).

Now, we turn to the electronics. It shall be seen that both the 477 and 485 shall be in remote/rem mode.

Hit the 477 RTL button and the 485 REM button to permit manual control.

Use the lower of the two buttons next to the gain ranges of the 477 to increase the gain (lower ranges).

If the overload (red) light of either 477 or 485 come on, reduce gain using upper button.

Now, consider the voltage displayed on the 417 LCD set to channel A- this is the output of the lock-in amplifier. It is of question of finding in which quadrant is to be found the maximum positive signal.

Fine variable phase can be changed using the central black knob of the 485; one can step through the quadrants using the 90°/180° button of the 485.

Proceeding through the quadrants, one should see the pattern zero, negative signal, zero, positive signal.

Where no quadrant is zero, go to the quadrant with the lowest value, and increase the phase slightly to see if the present quadrant value increases or decreases. If it increases, go to the next quadrant and continue increasing the phase variable, this should go to approximately zero.

Step through the quadrants to check the sequence zero, negative signal, zero, positive signal.

The phase variable and the quadrant in which is to be found the positive maximum should be passed to the software.

Software
Windows shall recognise all Bentham USB devices, without the requirement for additional drivers, however the USB camera of the TEL309 shall require separate drivers installed.

For all but the TEL309, the process to add new hardware should be followed once for each instrument before using Benwin+.

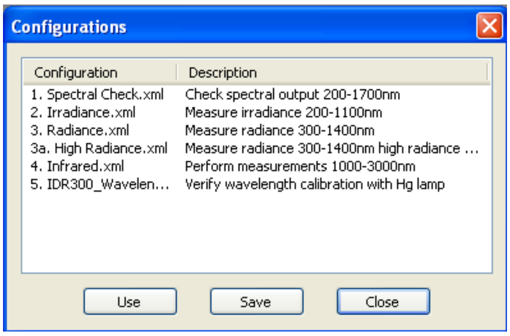
•Connect the USB to the monochromator and power on
•Wait until windows finds new hardware
•Allow windows to search for the required drivers automatically
•Perform the same process for the 417 detection electronics

To install the TEL309:-
•Power on and connect USB
•On CD locate TEL309 drivers, run setup.exe
•Proceed through installation

•Insert Benwin+ CD into computer, and double–click on setup. This takes you through the setup process, select complete installation
•A Bentham/ Benwin+ folder is created in c:/program files (local hard disk)
•A shortcut to Benwin+.exe shall be found also on the desktop

This system operates via a configuration manager to migrate between different measurement setups with facility. This is setup initially by the following operation:-

•Run Benwin+.
•You shall now be prompted with the following dialogue box:-



•Double click on the desired configuration
•The system is now ready for use.

Appendix 2: Verification of Monochromator Wavelength Calibration

Wavelength calibration is usually checked using a mercury lamp the output of which consists of discrete lines at defined wavelengths. The presence of mercury in overhead fluorescent tubes can act as a good replacement for a specific lamp.

The following describes calibration with a mercury lamp but in the case of this system, the same can be performed using the emission lines from the Xenon lamp, or by simply viewing the zero order contribution of each grating in turn.

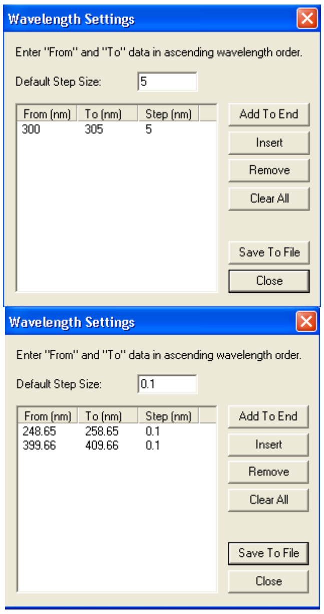
The following table shows the position of the mercury lines. Those marked in red are particularly strong lines, leading therefore to higher orders with a measurable contribution.

1st Order	2nd Order	3rd Order	4th Order	5th Order	6th Order	7th Order
184.91						
194.17						
226.22						
237.83						
248.2						
253.65	507.3	760.95	1014.6	1268.25	1521.9	1775.55
265.2						
280.35						
289.36						
296.73						
302.15						
312.57	625.14	937.71	1250.28	1562.85		
313.17						
334.15						
365.02	730.04	1095.06	1460.08	1825.1		
365.44						
366.33						
404.66	809.32	1213.98	1618.64			
407.78						
434.75						
435.84	871.68	1307.52	1743.36			
491.6						
496.03						
546.07	1092.14	1638.21				
576.96						
579.07						
690.7						
1013.98						

It is of course important to ensure that whilst observing the higher order lines, the order sorting filters of the monochromator are de-activated. This is done by going to instruments/ filter wheel and resetting the true insertion wavelengths with 0nm.

Use the tools/ create custom wavelength file facility of Benwin+ to define a scan around desired emission lines rather than scanning over the full range.

Go to tools/ create custom wavelength file, to view the following, left.



Set default step size, insert the number of lines required, double click on values to edit and finally save to file.

Choose a step size of minimum 0.15nm to view lines.

Scans using this file are initiated by going to scan/ scan set, select custom wavelength file and load file required, then scan as normal.

Please be aware of the slits presently in system. Having for example 5nm slits present and looking at the lines around 365nm, one will effectively see several lines which can distort the result and wrongly show lack of calibration.

In the case of infrared gratings where this procedure is of no use, gratings are set up with the zero-order position.

A Custom wavelength file and configuration (wavelength check) has been provided to check wavelength calibration through measurement of a CFL lamp. Post-scan, exporting to Excel running the macro provides all calculations.

Should a wavelength error exit, please contact Bentham.