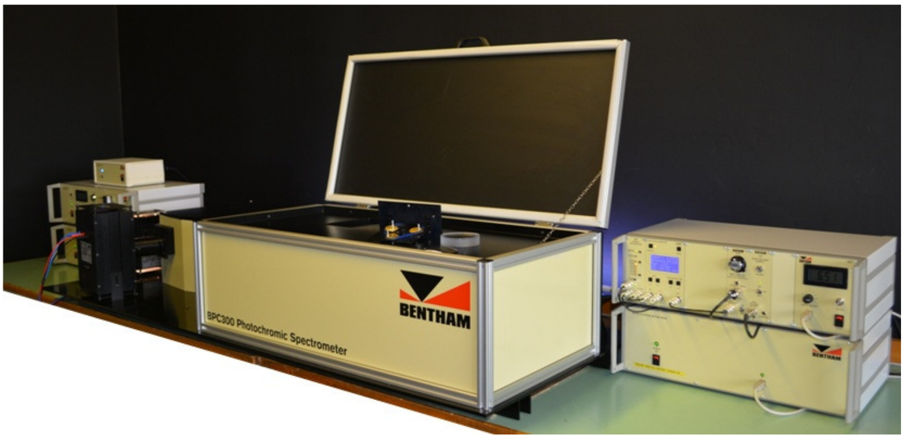
BPC300

PHOTOCHROMIC LENS CHARACTERISATION SYSTEM



USER MANUAL

Version 1 –October 2014

Bentham Instruments Limited

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1 INTRODUCTION

Thank you for your purchase of the Bentham BPC300 Photochromic Spectrometer. The documentation for this product consists of this User's Manual with reference made to specific component manuals where further information is sought. To get the most from this measurement system, please be sure to read all instructions thoroughly and keep them where they will be read by all who use the product.

2 GUARANTEE

Bentham Instruments warrants each instrument to be free of defects in material and workmanship for a period of one year after shipment to the original purchaser. Liability under this warranty is limited to repairing or adjusting any instrument returned to the factory for that purpose. The warranty of this instrument is void if the instrument has been modified other than in accordance with written instructions from Bentham, or if defect or failure is judged by Bentham to be caused by abnormal conditions of operation, storage or transportation. The warranty excludes consumable items such as replacement lamps.

This warranty is subject to verification by Bentham, that a defect or failure exists, and to compliance by the original purchaser with the following instructions.

Before returning the instrument, notify Bentham with full details of the problem, including model number and serial number of the instrument involved. After receiving the above information, Bentham will issue an RMA reference number and provide shipping instructions.

After receipt of Shipping instructions, ship the instrument “carriage paid” to Bentham. Full liability for damage during shipment is borne by the purchaser. It is recommended that instruments shipped to us be fully insured and packed surrounded by at least two inches of shock-absorbing material. Specific transit packaging must be used.

Bentham reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Bentham, and Bentham neither assumes, nor authorises any other person to assume for it, any liability in connection with the sales of Bentham's products.

NOTHING IN THIS GUARANTEE AFFECTS YOUR STATUTORY RIGHTS.

3 NOTICE FOR CLIENTS IN EUROPEAN UNION

This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste.

Bentham are fully WEEE compliant, our registration numberis WEE/CB0003ZR.

Should you need to dispose of our equipment please telephone +44 (0) 113 385 4352/4356, quoting account number 135419

4 CONTACT BENTHAM

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5 SYSTEM REQUIREMENTS

Minimum hard disk space: approx. 100MB

Minimum RAM: 2 GB

Windows 7, Windows 8 (32-/64-bit) operating systems

4x USB- ports

6x main sockets

Bench space: 1m deep x 3m wide (including space for computer)

Nitrogen gas supply where measurements below ambient are required

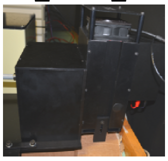
Component	Current (220V) (A)	Power consumption (W)
TMc300	0.1	22
605- IL1	1.9	350
605- IL_COND_BEAM	*1.9*	*350*
706- IL6	*0.3*	*50*
417	<0.1	<10
PMC MAC	*1.9*	*350*
TOTAL	**<6.9**	**1132**

Table 1: BPC300 Electrical Supply Requirements

6 SYSTEM COMPONENTS

1x BPC300 Chamber on plinth

1 x IL_Solar_AM2



1 x TMc300-F-U fitted with T324H0U25 and T312R0U5 diffraction gratings, OS400 and OS700 order sorting filters and 1.85mm two entrance and exit slits

1x IL1 Quartz Halogen Source

1x IL6_DEUT Deuterium Source

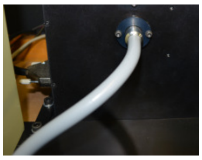
2 x 605 Constant Current Power Supply

1x 706 Deuterium Lamp Supply

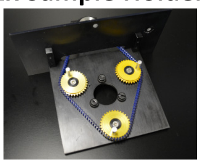
1x COL1 Collimator

1x 218 Optical Chopper

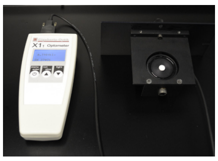
1x Fibre Bundle



1x Sample Holder



1x X11 Meter and VL3704-4 Luxmeter



1x Thermometer

1x 417 Detection Electronics	1x PMC MAC controller
	
1x Benwin+ CD 	

Miscellaneous

- 1x 5-pin amphenol cable
- 2x BNC signal cables
- 1x HV BNC cable
- 2x Red and Black lamp cables
- 1x Red, Black, Blue cable
- 1 x PC
- 1x 25-way cable (thick)
- 1x 25-way cable (double)
- 3x USB cables
- 1x RSR232- USB cable
- 5x UK mains cables
- 8x M3x 12 screws

7 SYSTEM OVERVIEW

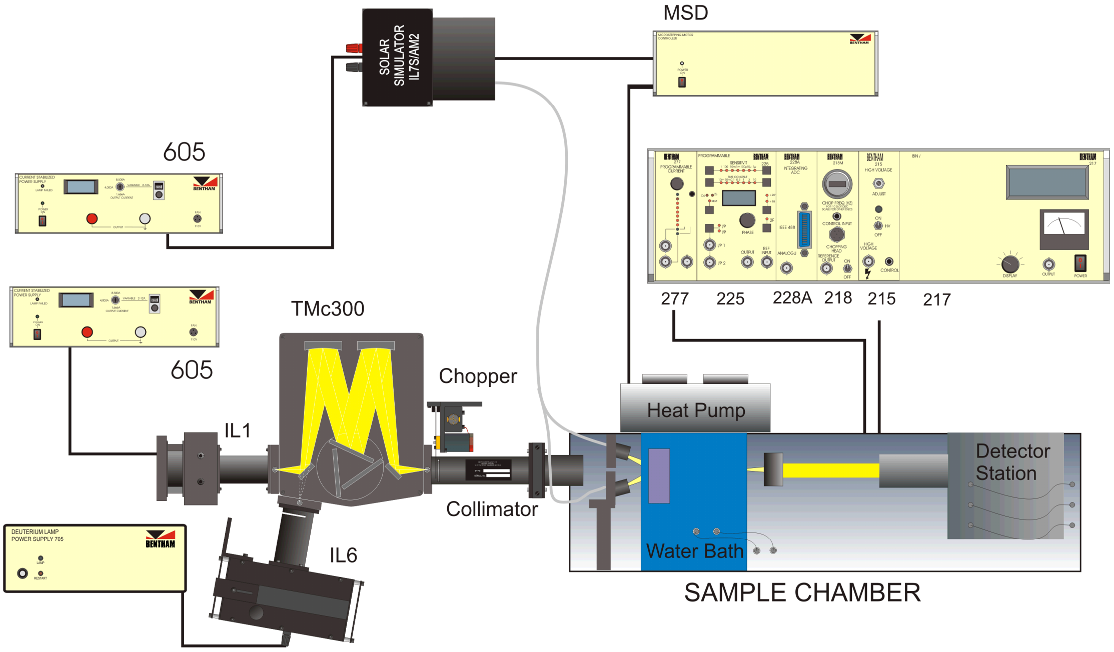


Figure 1 BPS300 System layout

The Bentham BPC300 is a turn-key solution for the quick and accurate characterisation of photochromic lens transmission in accordance with ISO 8980-3: 2013 and ISO 12312-1:2013 (test methods applicable to ISO 12312-1:2013). Lenses of a range of sizes can be tested over a wavelength range of 280nm to 780nm in the faded, darkened and faded back states.

A monochromatic probe, 280-780nm, is generated from a deuterium and a quartz halogen source by a Bentham TMc300 single monochromator. This probe is made to be incident on the sample under test in the determination of spectral transmittance whilst to activate the photochromic, the sample is irradiated by an AM2 solar simulator. The output of this simulator may be set to different levels, and filtered where required. A dual optical path system is implemented to speed up measurements.

Of the light incident on the system detector station- transmitted by the sample from both sources- only that from the monochromatic source is sought. Discrimination of the two components is achieved by modulating the optical probe on a known carrier wave using an optical chopper, recovering the signal with a fully automated DSP lock-in amplifier and employing spatial filtering to reduce the amount of transmitted light from the solar simulator.

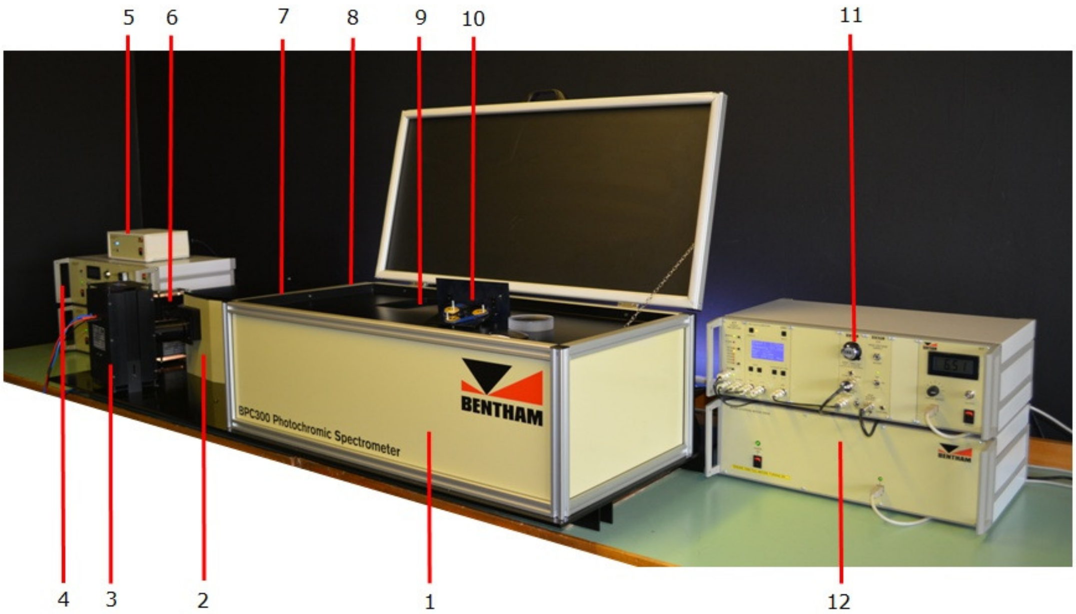
The sample is immersed in a temperature controlled water bath for the purposes of maintaining sample temperature during solar simulator irradiation and to permit evaluating the photochromic response at different temperatures. A computer-controlled thermoelectric heat pump is used to set the temperature required for each measurement and maintain the sample temperature to within ± 0.2°C at the specified levels. A correction may be implemented taking into account transmission values measured in air as opposed to water.

The BPC300 system is fully automated by the Benwin+ proprietary Windows application in which measurement profiles may be defined, the procedure culminating in the production of a measurement report which includes the evaluation of all parameters required by these standards, amongst which:-

Symbol	Quantity
τ_{V0}	Luminous transmittance in the faded state at (25±2)°C
τ_{V1}	Luminous transmittance in the darkened state at (25±2)°C
τ_{V0} / τ_{V1}	Photochromic Response
τ_{VW}	Luminous transmittance at (5±2)°C
τ_{VS}	Luminous transmittance at high temperature (5±2)°C
τ_{VA}	Luminous transmittance at reduced solar simulator level and (25±2)°C
τ_{SUVA}	Mean UVA spectral transmittance weighted by AM2
τ_{SUVB}	Mean UVB spectral transmittance weighted by AM2
Q_{sign}	Visual attenuation coefficient for red, green, blue and yellow incandescent and LED traffic signals
τ_{sb}	Solar blue light transmittance
Also reported are:	
	Lens category
	Colourimertric parameters: CIE 1931 & CIELab
	The rate of darkening and fading may also monitored at a single wavelength

Table 2: Parameters reported by BPC300

7 OVERVIEW OF HARDWARE INSTALLATION



1	BPC300 Chamber including detectors	**7**	(Unseen) COL1 collimator/218 optical chopper
2	TMc300 Monochromator	**8**	(Unseen) IL_COND_BEAM with bifurcated fibre bundle
3	IL6_Deut Deuterium Source	**9**	Water Bath
4	(Two) 605 constant current supplies	**10**	Sample Holder
5	706 deuterium lamp supply	**11**	Detection electronics
6	IL1 QH Source	**12**	PMC MAC housing drive for and temperature control

Figure 1: BPC300 System overview

The following merely provides an overview of hardware installation, the finer points of which will be undertaken in the system installation by Bentham personnel.

It is recommended to locate the BPC300 system on a bench at least 1m deep x 3m wide with the computer and working area reserved to the right hand side.

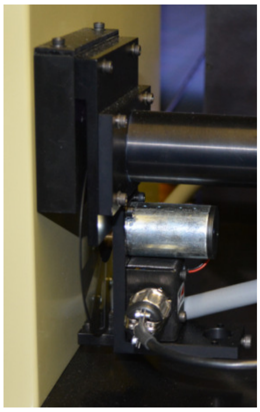
1 Locate the BPC300 chamber and plinth to the centre of the bench.

2 To the left hand side of the BPC300,stack the two 605 constant current power supplies and 706 deuterium lamp power supply

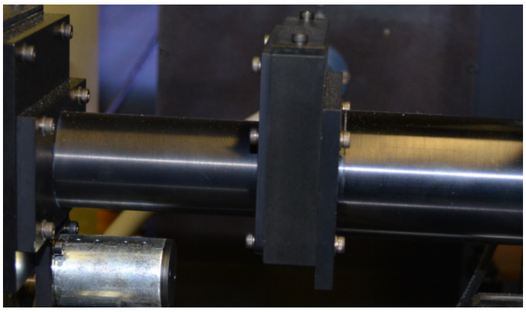
3 To the right hand side of the BPC300, stack the PMC MAC and 417 detection electronics

4 Place the TMc300 monochromator on the plinth to the left hand side of the BPC300 chamber, mains and USB connector face toward rear.

5 Fit the 218H optical chopper via the chopper mounting plate to the exit port of the TMc300 monochromator using two M3 screws provided.



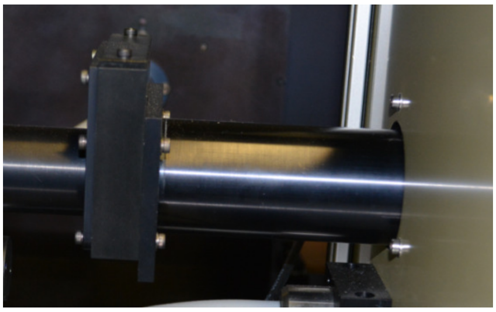
6 Attach the COL1 to the optical chopper assembly using four M3 screws provided, iris diaphragm side toward the BPC300 chamber.



7 Slide the TMc300/ collimator ensemble on the plinth to engage with the aperture to the left hand wall of the BPC300 chamber.

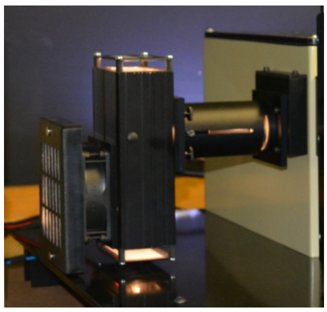
Attach the TMc300 to the plinth from the underside of the latter using M6 screws provided.

4



8 To the TMc300 entrance slit opposite the exit slit to which the chopper and collimator have been mounted, mount the IL1 quartz halogen illuminator using four M3 screws provided.

Connect the IL1 to one of the 605 constant current power supplies using red and black power cables and fan.



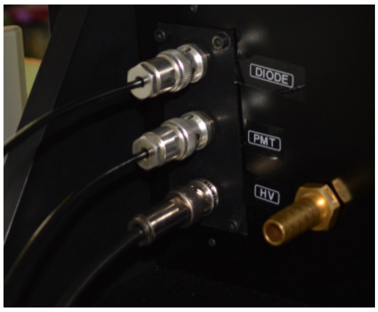
9 To the TMc300 entrance slit perpendicular to the last, attach the IL6_Deut Deuterium illuminator using four M3 screws provided, dropping the supporting feet of the source to bear the load.

Connect the IL6_Deut to the 706 deuterium lamp power supply using the red, black and blue cables provided.

10 At the 417 unit, connect 218 optical chopper to the 218 optical chopper mounted to the exit port of the TMc300 monochromator using 5-pin amphenol cable.

The “reference output” of the 218 should already be connected to the “ref” port of the 496 DSP lock-in amplifier.

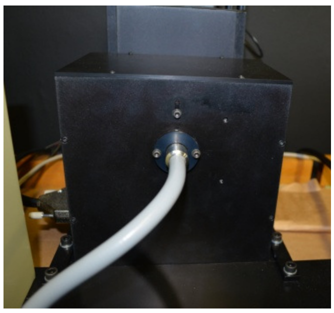
11 To the right read of the BPC300 chamber are the detector outputs. Connect “PMT” to 477 input 1, “diode” to 477 input 2 and “HV” to the 215v HV supply.



12 To the rear of the plinth, mount the IL_COND_BEAM AM2 solar simulator.

Connect red and black power cables and fan to 605 PSU.

13 Fit the bifurcated fibre bundles to the IL_COND_BEAM and then each branch to the BPC300 chamber.



14 To the rear of the PMC MAC unit (ensuring power off) connect:-

Heat pump port: Connect to heat pump to rear of BPC300 chamber using thick 25-way cable provided.

Filter wheel port: Connect to IL_COND_BEAM using 25-way cable split into two cables provided.

RS232 port: Connect RSR232-USB convertor to computer.

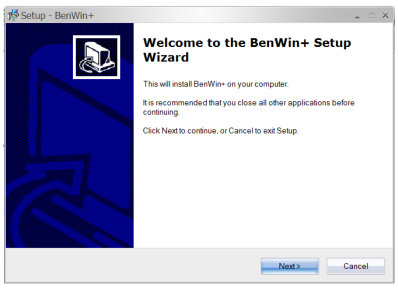
15 Connect mains cables to two 605 PSUs, 706 PSU, TMc300 monochromator, 417 and PMC MAC units. Connect TMc300, PMC MAC and 417 to computer using USB cables provided.

16 It is recommended to power on the 605 of the IL_COND_BEAM first and le the xenon lamp strike first before powering on the remaining of the system. This is merely observed as a precaution.

8 SOFTWARE INSTALLATION

1 Insert the CD into your CD drive, wait for auto-run to present an installation screen

2 Select Benwin+, follow the installation procedure, no intervention required other than hitting “next”.

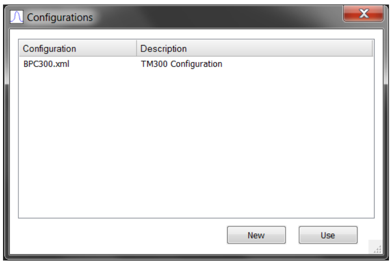


The Benwin+ program will be installed to C:\Program Files\Bentham\Benwin+ (Program Files x86 for 64-bit OS), whilst user folder will be created in C:\Users\Public\Documents\Bentham\BenWin+ folder.

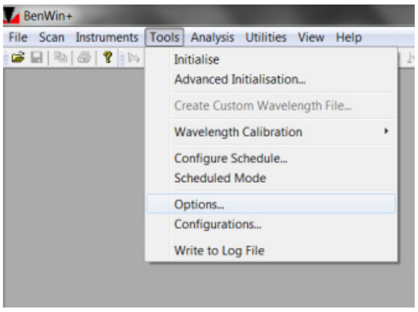
A desktop short-cut will also be created.

3 Ensure that the TMc300, PMC MAC and 417 are connected to USB and powered on. Run Benwin+ from desktop icon

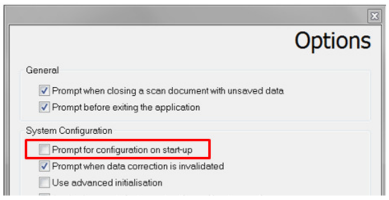
5 When presented with the configuration screen, over, double click on the BPC300 configuration. You will hear the motion of motors in the TMc300 monochromator as the systems moves the turret and filter wheel to parking position.



6 Go to tools/ options



7 De-select “Prompt for configuration on start-up”, then hit apply (bottom, right).

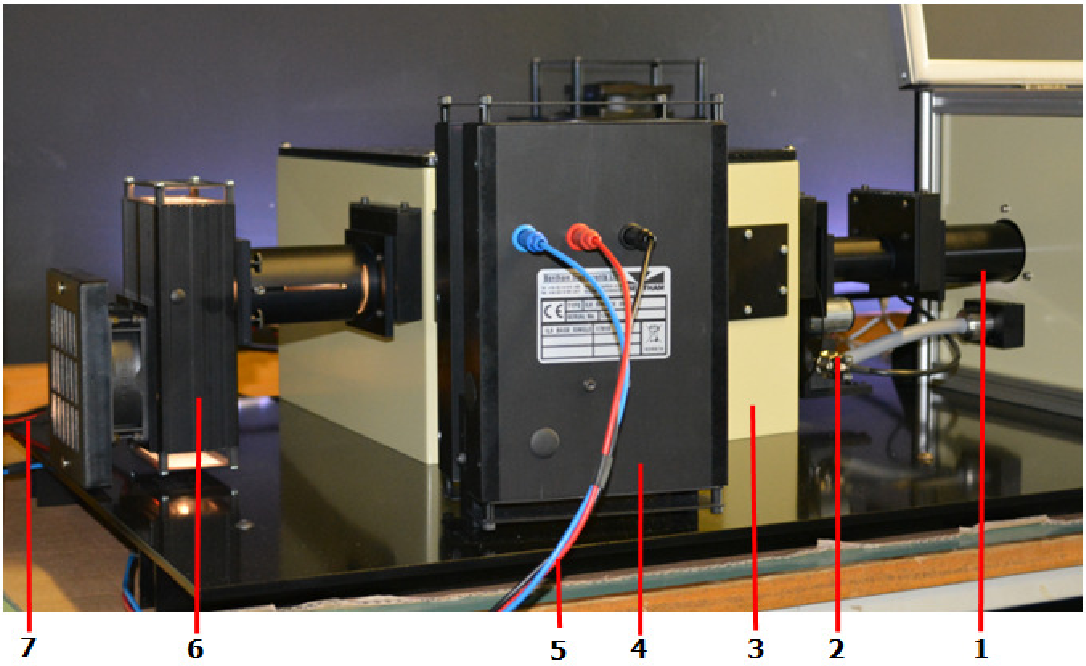


8 Close Benwin+

9 GETTING TO KNOW THE BPC300 SYSTEM

9.1 MONOCHROMATIC PROBE SOURCE

9.1.1 INTRODUCTION



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1	COL1 Collimator	**5**	Power cables IL6_Deut to 706 PSU
2	218 Optical Chopper	**6**	IL1 QH Visible illuminator
3	TMc300 Monochromator	**7**	Power and fan cables IL1 to 605 PSU
4	IL6_Deut Deuterium UV illuminator		

Figure 2: IL1 illuminator

The probe for transmission measurements is the collimated, chopped, monochromatic output from a Bentham TMc300 monochromator/ Quartz halogen lamp/ Deuterium Discharge lamp combination.

Two light sources are input to the TMc300 monochromator for optimal coverage of the 280-780nm spectral region for two reasons, firstly since the irradiance of the IL1 quartz halogen source in the UV is low, and secondly from a consideration of stray light performance of a single monochromator which concern is absent where a UV source is used.

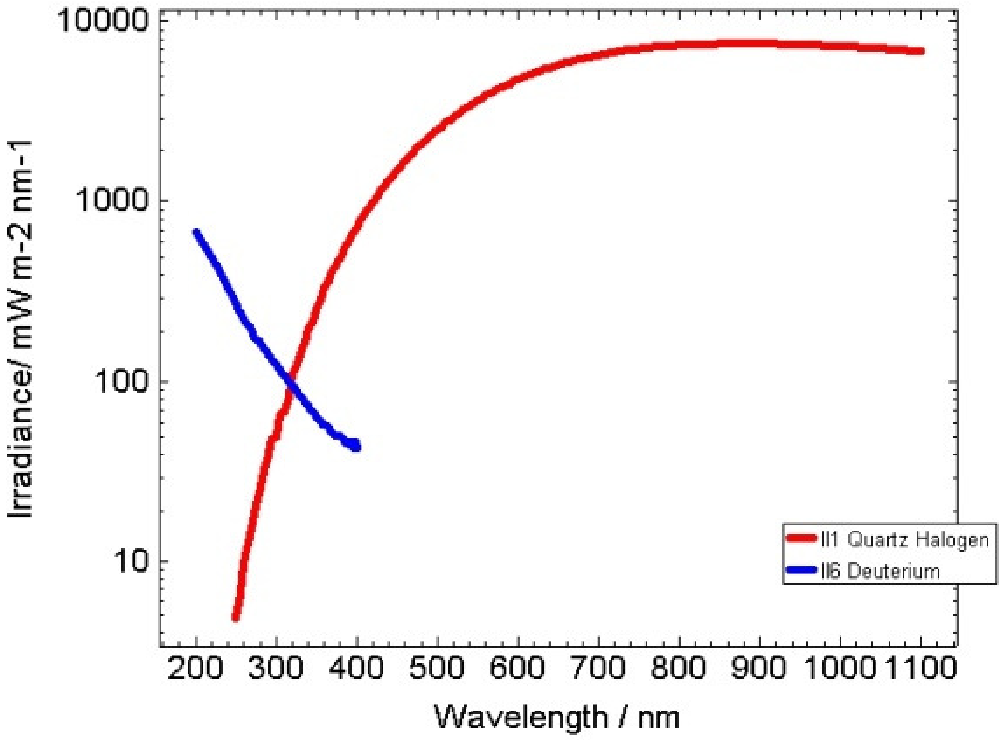


Figure 3:- Example irradiance at entrance slit of IL1 and IL6_Deut

9.1.2 IL1 QUARTZ HALOGEN ILLUMINATOR

Figure 3: IL1 illuminator

The IL1 is a general-purpose light source for use in the UV, visible and infra-red spectral regions from 350nm to 2.5µm. A 100W quartz halogen lamp, controlled by a Bentham 605 current stabilised power supply is employed

A single quartz condenser lens is used to fill the height and width of the slit and to match to the f/4 optics of the monochromator. The quartz halogen lamp is unsurpassed for stability by any other source and should always be used where it provides sufficient output in the wavelength region of interest.

This source is coupled directly to the monochromator exit slit opposite the exit slit, using 4 M3 screws. On shipping, the lamp alignment was optimised.

The operating conditions of this source provided by the 605 power supply, is as follows:-

Source	Current (A)	Illumination time (mins)	Warm-up Time (mins)	Rated Life (hours)
100W QH	8.500	Instantaneous	5	2000

Table 3: IL1 operating conditions

This lamp should not be run at a higher current, nor a lower current since this may equally curtail lamp lifetime by breaking down the halogen cycle.

A fan is located to the rear of the source, and should be powered on at all times.

Do not touch the QH bulb with bare fingers.

Please note that the housing becomes very warm in operation.

Guidance on lamp replacement is provided in annexes XXX.

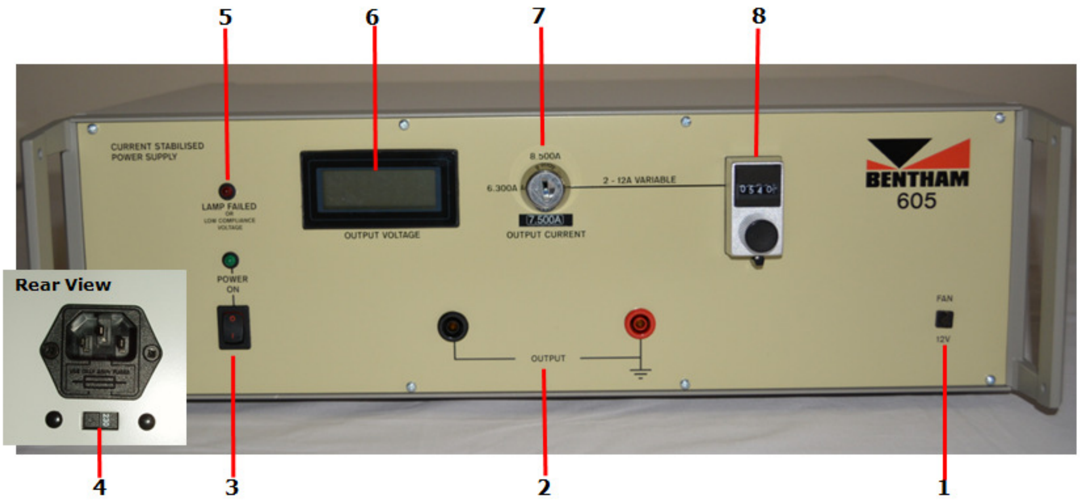
For further information on this and other lamps, please see our technical guide on light sources.

9.1.2 CONSTANT CURRENT POWER SUPPLY

For the IL1 (and indeed the IL_COND_BEAM) a 605 constant current power supply is provided.

The 605 is a constant current power supply, with a key-operated switch to provide three calibrated current settings, and an additional variable 2-12A, two decimal place dial controlled setting. A three-pin socket for lamp fan operation is situated on the lower right of the front panel.

The operating voltage of the 605 has been set up at Bentham according to where the device is sent, as indicated by a toggle selector, found underneath the mains connector, and an appropriate fuse (plus a supplement) fitted (220V- 2.5A slow blow).



1	12V fan output	**6**	LCD output voltage display
2	Constant current output	**7**	Key-switch current selector
3	On-off switch and LED	**8**	Variable current dial
4	Mains voltage selector		
5	Lamp failure indicator		

Figure 3: 605 Constant current power supply

In the BPC300 system, both 605 power supplies are set to operate at 8.5A. The current setting keys of both 605s have been removed to the side to prevent inadvertent changing of the current selected.

In operation, ensure the correct polarity is respected at all times, connecting red to red and black to black from lamp to 605, and that the fan is connected. Depress the on/off switch to illuminate/ extinguish lamp.

It is of use to note the voltage displayed on the 605 LCD (negative since ground positive). This voltage represents that dropped over the source and cabling and can be used to determine source condition.

One of the failure mechanisms of the QH lamp, for example, is “bridging” or short-circuit of part of the filament, leading to a correspondingly lower voltage and reduced light output which would be seen by a reduction in voltage. Quartz halogen lamps are operated at slightly under their nominal rating, and as such the voltage readings may be lower than nominal.

9.1.3 IL6_DEUT DEUTERIUM ILLUMINATOR

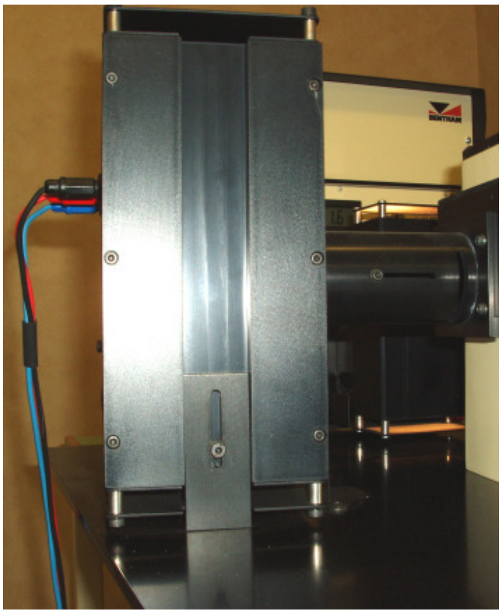


Figure 5: IL6_Deut Deuterium illuminator

The IL6 houses a 30W Deuterium lamp. Using a, dual-element lens (f/1 input, f/4 output) a precise match to the acceptance cone of the monochromator is achieved, thus maximising light transfer whilst minimising scattered light.

This source is directly mounted to the monochromator entrance slit, perpendicular to the exit slit, using four M3 screws. Once the lamp has been attached to the entrance slit, it is necessary to position the two "feet" of the housing, as indicated in figure 1, to bear the weight of the unit.

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.

These lamps use a heated cathode which is made of a tungsten filament, typically coated with a highly emissive material. The starting sequence of these lamps consists of typically around thirty seconds application of heater current prior to establishing the arc.

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. The output of these lamps is from around 112nm to 900nm, however the actual output obtained is largely related to the envelope used. The output is line free up to around 360nm.

The operating conditions of this source provided by the 706 power supply, is as follows:-

Source	Current (mA)	Illumination time	Warm-up Time (mins)	Rated Life (hours)
30W Deuterium	300	After application of heater for ~30s	10	500

Table 3: IL6_Deutr operating conditions

Figure 6: Load bearing feet dropped and locked in placed by tightening screw

On shipping, the lamp alignment was optimised.

Do not touch the deuterium lamp with bare fingers.

Guidance on lamp replacement is provided in annexes XXX

For further information on this and other lamps, please see our technical guide on light sources.

9.1.4 706 DEUTERIUM LAMP POWER SUPPLY

Figure 6: 706 Deuterium lamp supply

The 706, on switch on, provides the Deuterium lamp with the required ~thirty seconds of heater current before establishing the arc, during which time the starter LED is indicated. If the arc fails to establish, the start sequence will repeat. In such a case ensure electrical corrections are correct, This may indicate lamp failure.

There are three electrical connections between the 706 and the IL6_Deut, anode (red), cathode (black) and heater (blue). The 706 is fitted with a switched mode power supply and a line fuse suited for location fitted.

9.1.5 TMC300-F-U MONOCHROMATOR

The monochromator of this system is a Bentham TMc300-F-U, 300mm focal length single monochromator.

1	110/220V fuse selector	**5**	Exit fixed slit carrier
2	Mains input and switch	**6**	(Unseen) Entrance one fixed slit carrier
3	Power & USB indicators	**7**	Entrance two fixed slit carrier
4	USB input		

Figure 4: TMc300-F-U monochromator

In the TMc300 monochromator, the following ruled planar diffraction gratings are mounted on a turret to permit use over a wide spectral range.

Line density (g/mm)	λ Blaze (nm)	Max λ range (nm)
2400	250	200-600
1200	500	300-1100

Table 2: Diffraction gratings installed

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.

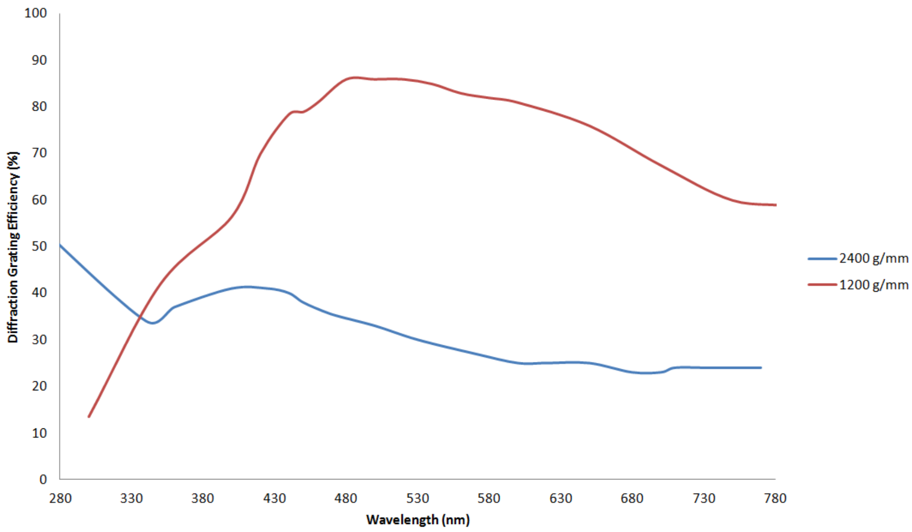


Figure 5: Typical diffraction grating efficiency

The TMc300 includes a two-stage encoder which allows the unit to be sent to a fixed point (negative limit) which is used as a datum, to which position the turret is sent on software initialisation.

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).

An eight position filter wheel, populated with the following long pass, higher diffraction order blocking filters, is situated behind the entrance slit. A blank disk, in position eight stops light from entering the monochromator during zero-offset measurements.

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

Table 3: Filter wheel content

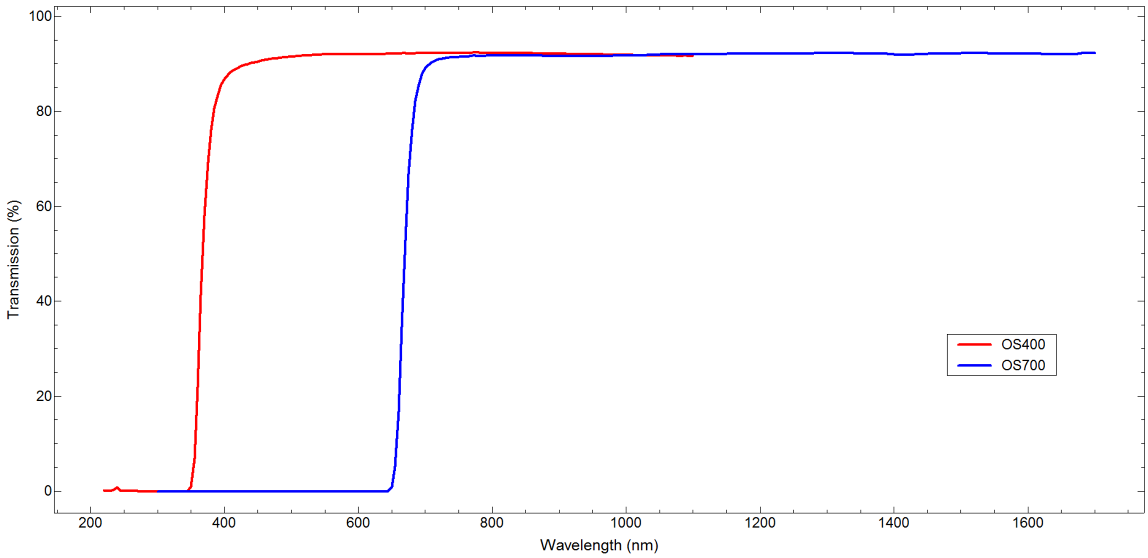


Figure 6: Typical OS filter transmission

The entrance and exit ports are fitted with fixed slits to define system bandwidth, 1.85mm.

The following table shows the bandwidth obtained for the monochromator and gratings of this system with a range of slit widths, those supplied being highlighted.

Grating Line Density (g/mm)	2400	1200
Dispersion (nm/mm)	1.35	2.70
Slit widths (mm)	Bandwidth Produced (nm)	
0.05	0.07	0.14
0.1	0.135	0.27
0.2	0.27	0.54
0.37	0.5	1.00
0.4	0.54	1.08
0.5	0.675	1.35
0.56	0.755	1.51
0.74	1	2.00
1	1.35	2.70
1.12	1.515	3.03
1.48	2	4.00
1.85	**2.5**	**5.00**
2	2.7	5.40
2.78	3.755	7.51
3.7	5	10.00
4	5.405	10.81
5.56	7.51	15.02
8	10.81	21.62
10	13.51	27.02

Table 4: Monochromator bandwidth

Fixed slits are changed by the following method.

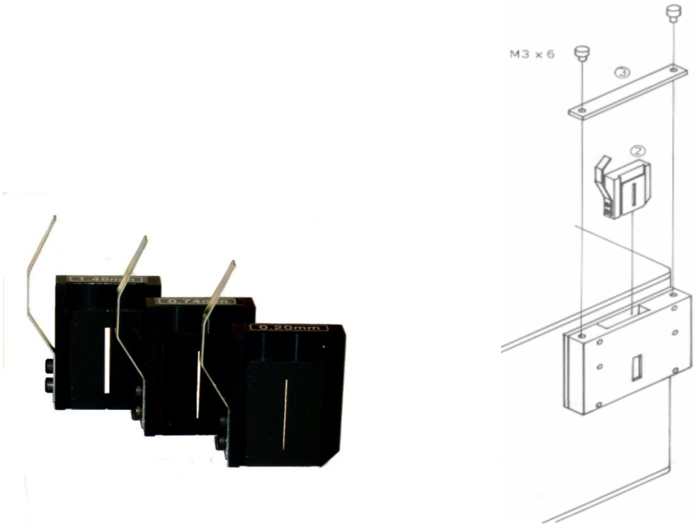


Figure 7: Fixed slits and insertion thereof

To remove fixed slits, remove cover with M3 Allen key and using pincers, pull out slit in place.

To insert slits, place slit in holder with etched side facing away from monochromator, flat rear of slit against the monochromator, pushing fixed slit down, firmly into place.

It is important that the slits are installed in the correct orientation, else a wavelength error results.

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.

The TMc300 is fitted with a switch mode power supply, and include a 110/ 220V selectable fuse holder (220V – 630mA anti-surge; 110 V- 1260mA anti-surge). Please ensure that the white indication arrow points to the mains voltage used.

Never touch the diffraction gratings nor mirrors inside the TMc300.

Do not attempt to clean any contamination- damage can only result.

Do not subject monochromator to violent physical shock- this may invalidate wavelength calibration

Please see appendix XXX for information concerning checking the wavelength calibration of the TMc300

For further information on monochromators, please see our technical guide on monochromator operation.

9.1.6 218 OPTICAL CHOPPER

At the exit slit of the monochromator is mounted an optical chopper. This device is fitted with a blade having a number of slots to modulate the monochromatic probe at a known frequency. To the base of the chopper is an IR detector-receiver which encodes the chopping frequency.

The optical chopper is driven by the 218M module, the reference being returned from the chopper to the 218 and passed to the DSP lock-in amplifier for signal recovery.

Figure 9:- Optical chopper at exit port.

9.1.7 COL1 UV VIS COLLIMATOR

The chopped probe beam is delivered to the sample chamber via a collimator.

Figure 10:- Collimator

The collimator uses a 2-lens (silica) system with interchangeable apertures to allow the user to optimise the throughput/power trade-off.

The first lens produces an image of the source with unity magnification at the plane of the interchangeable aperture. The second lens is positioned at its focal length of 150mm from the aperture.

An iris diaphragm is fitted after the second lens and allows the beam diameter to be varied over the range 2 – 20mm.

In this setup, a 1.17mm aperture is used, and before the sample chamber there exists a brass aperture to further ensure collimation. The variable iris is therefore adjusted to overfill this aperture.

9.2 AM2 SOLAR SIMULATOR

9.2.1 OVERVIEW

The chopped probe beam is delivered to the sample chamber via a collimator.

According to standards, the photochromic activation beam should have a spectral output as close as possible to that of AM2 and there should exist the following variants:-

Activation light level	Condition
Standard	50 klux
Moderate	15 klux

Table 6: Activation beam conditions

The activation beam is based around the output of a Xenon short arc lamp.

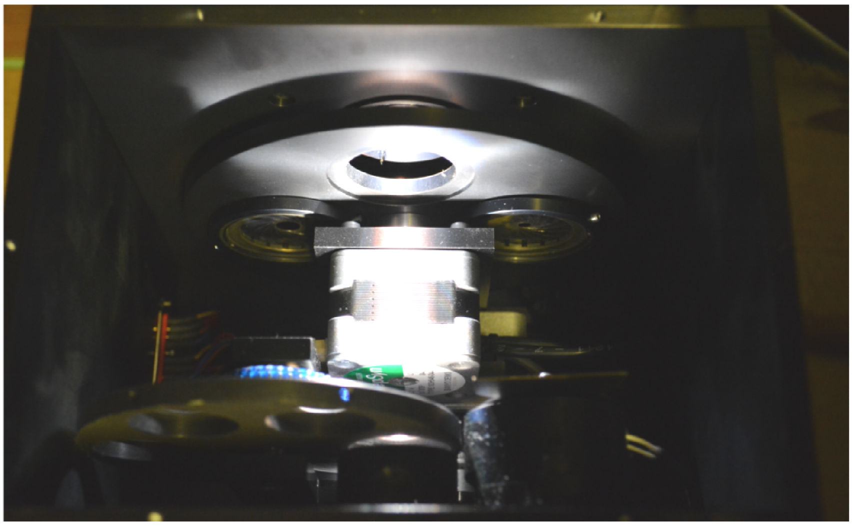


Figure 11:-Inside activation beam source

On the output of the Xenon lamp is a chamber containing two filter wheels, one of which contains four variable apertures, the other an eight position filter wheel destined to hold 25mm diameter filters. The only filter presently fitted in the latter is a with long pass filter for the measurement under night driving conditions. All elements are computer controlled.

9.2.2 XENON SHORT ARC LAMP

The Bentham IL7 Xenon source consists of 150W Xenon lamp operated from a Bentham 605. The 605 destined for use with this lamp is fitted with a time elapse indicator to monitor usage. This lamp operates at 8.500A. Always ensure that the fan is connected. (Please see section 2.2.2 for further information on the operation of the 605 supply).

Light from the Xenon lamp is collected by two silica lenses and focussed on the end of a quartz fibre bundle, the source output to the sample chamber.

The Xenon short arc lamp comprises two electrodes sealed in a quartz envelope, in which is present xenon gas. The cathode is designed to be physically narrow to ensure that it runs at a high temperature, and is doped, both to ensure that it emits as many electrons as possible. The anode is much larger to withstand being inundated with electrons. The distance between the cathode and may be up to several mm.

A starter is employed to initially drop a high voltage across the electrodes to establish the arc.

In general the Xenon lamp provides a higher UV output and less IR than the quartz halogen lamp, however the continuous spectrum is superimposed by unstable line emission which may not be desirable in some uses.

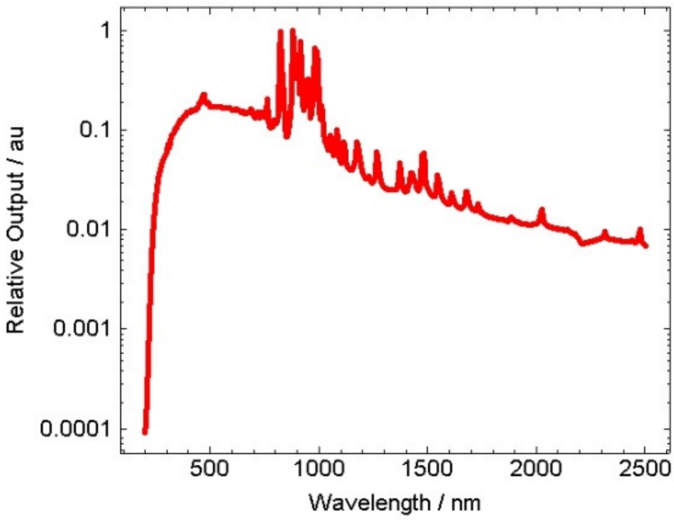


Figure 12: Relative spectral shape of Xenon lamp output

The operating conditions of this source provided by the 605 power supply, is as follows:-

Source	Current (A)	Illumination time (mins)	Warm-up Time (mins)	Rated Life (hours)
150W Xenon	8.500	Instantaneous	5	1000

Table 7: IL_COND_BEAM operating conditions

9.2.3 APERTURE WHEEL

Close to the Xenon lamp is a wheel carrying four adjustable iris diaphragms. Each may be adjusted to effectively reduce the aperture of the lens. The various light levels required by the standard are obtained by varying the opening of these irises. Each iris can be locked into place once set.

Adjustment is effected by loosening grub screw with hex key and using key as lever to rotate the iris ring. Once the desired aperture is obtained, the grub screw should be tightened (paying attention not to over tighten and damage iris).

9.2.4 FILTER WHEEL

An eight position filter wheel is provided to allow mounting of filter where required. No filters are currently fitted.

The filter wheel accepts 25mm diameter filters, held in place by a radial grub screw.

9.2.5 SHUTTER

A computer controlled shutter is found between the filter wheel and the filter holder, used to switch on/off activation.

9.2.6 AM2 FILTER HOLDER

Standards require an activation beam having a spectral shape as close as possible to AM2. An AM2 filter is duly placed in front of the quartz fibre bundle output of the AM2 simulator.

9.2.7 QUARTZ FIBRE BUNDLE

Light from the activation source is transported via quartz fibre bundle. This bundle is bifurcated into 4mm diameter bundles, at the sample chamber side. No optics is then used to ensure uniform illumination of the sample.

9.2.8 SETTING UP ACTIVATION BEAM

The spectral output and levels of the activation beam were set in factory. Changing lamps, however, will inevitably change the output of the source. Given that no separate spectroradiometer be provided with this system, a photometric detector is used to set up the activation.
An X11 optometer and VL3704-4 photometric detector has duly been provided for the measurement of illuminance. The calibration data of the photometric detector is held on EEPROMs in their connectors. It is recommended to have this device calibrated yearly.

The VL3704-4 is designed for immersion in water and mounted to a sample holder for insertion in the BPC300 sample chamber.

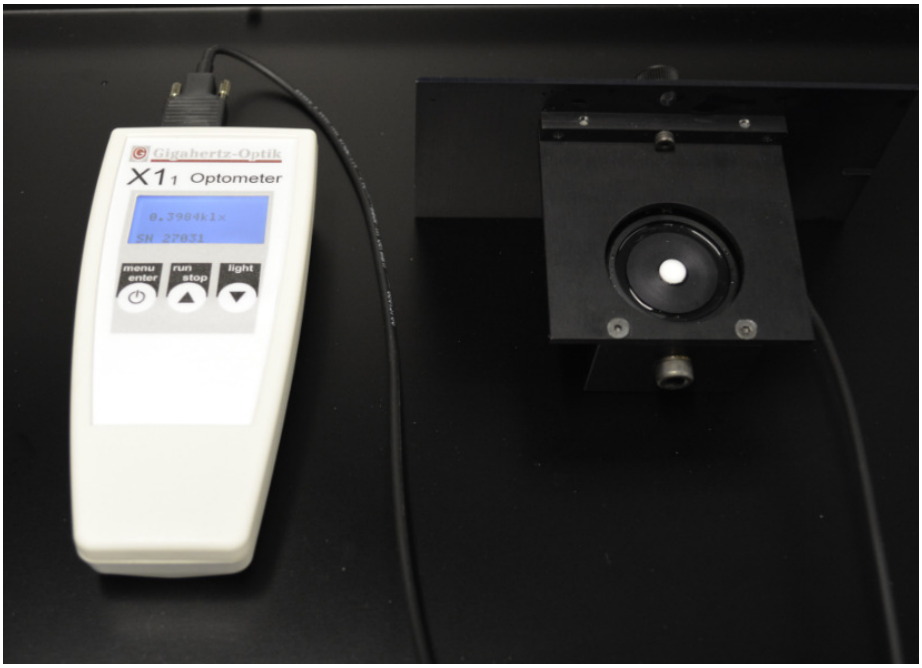


Figure 13:- Meter and filter radiometer in holder

In use the VL3704-4 should be connected to the X11, and the X11 powered on. After a brief start-up sequence, the illuminance in klx will be reported directly. The run/ stop button can be used to freeze the value.
Where it be required to increase / decrease the illuminance of the conditioning beam, this can be performed by removing the cover of the filter section of the AM2 source, loosening slightly the radial grub screw of the iris diaphragm. Rotating gently the grub screw allows opening/ closing of the iris as required. When the required illuminance is achieved, tighten the grub screw to lock the position.

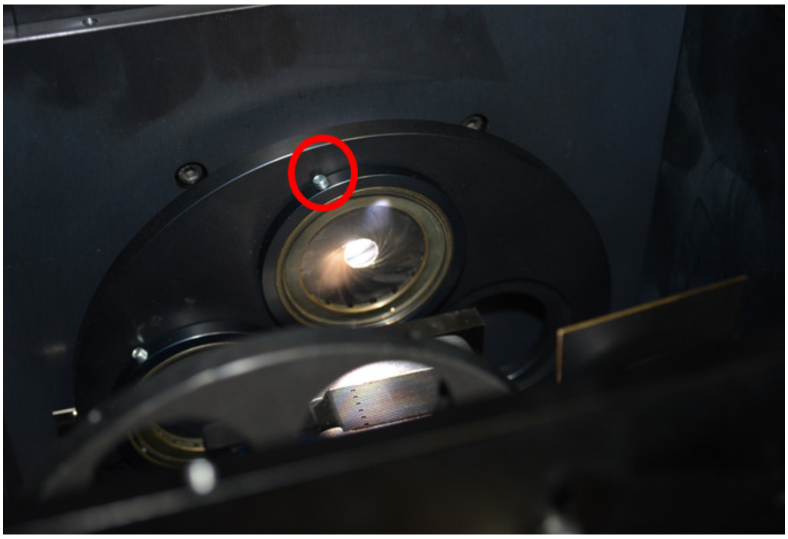


Figure 14:- Radial iris diaphragm grub screw used to open/ close iris

It is good practice to regularly apply this procedure of verifying the illuminance of the conditioning beam to ensure correct measurement.

9.3 TEMPERATURE CONTROLLED WATER BATH

9.3.1 OVERVIEW

The sample chamber is designed to be a light-tight enclosure. There exists a purge port to the rear of the chamber to permit nitrogen purging. This obviates the effect of condensation on the exterior of the water bath during lower temperature measurement.

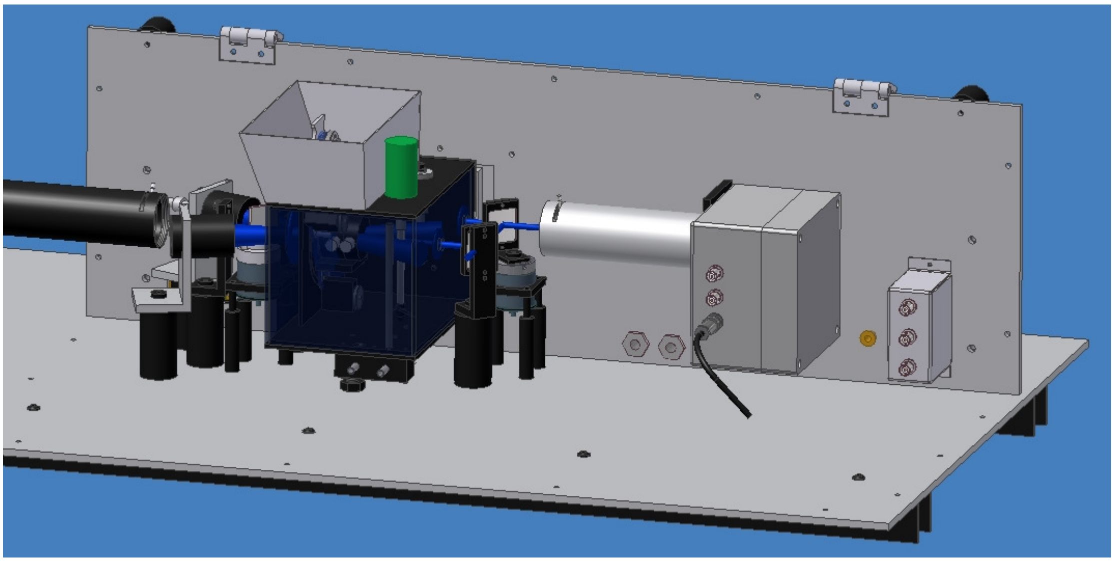


Figure 15: Sample chamber layout

Inside the sample chamber is situated the sample water bath, heat pump, and relay optics.

Under the lid there exists a drip tray to protect the optics when installing/ removing samples.

9.3.2 WATER BATH

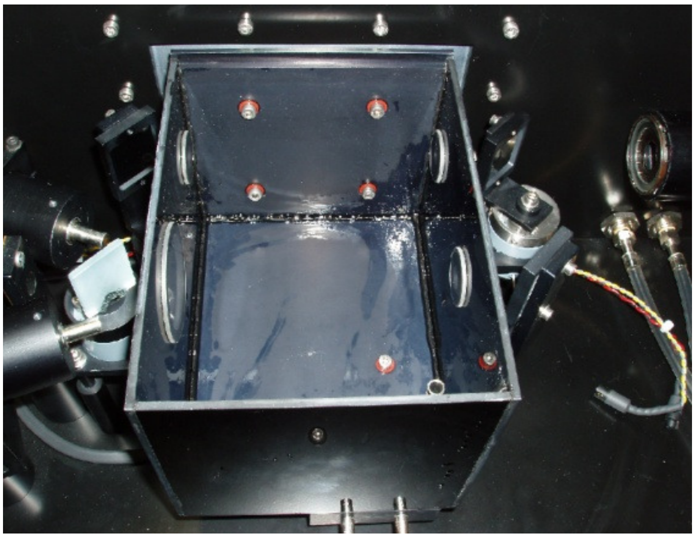


Figure16:- Water bath

The water bath design was based on three main criteria:-

That scatter of the conditioning beam into the monitor beam should be minimised

That there should be the minimum of components permanently mounted in the water bath

That the bath should be removable from the heat pump in the event that the heat pump need repair

1. Minimising scatter

The optical arrangement of the conditioning beam ensures no direct path between the two, but inevitably there will be scatter when the conditioning beam meets the wall of the bath.

The bath lid and end walls are made from 3mm thick plates of blackened glass (NG1). Transmission is typically 0.0001%, and reflection from the water/ glass interface is typically 0.34%.

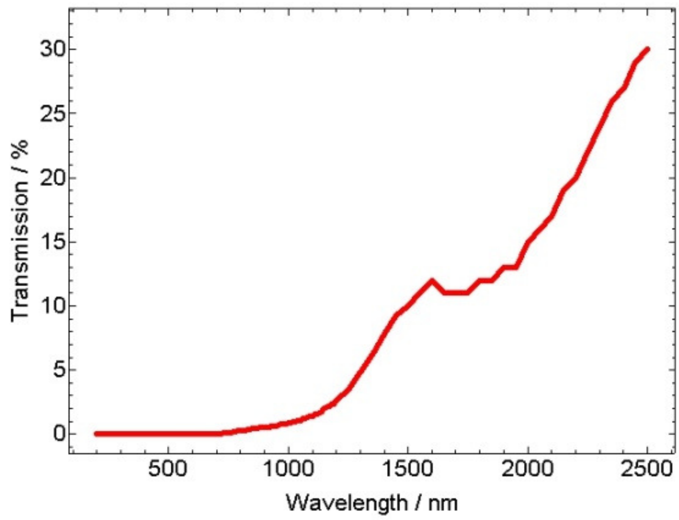


Figure 17:- transmission of 1mm NG1 glass

The floor of the bath, the removable lid and the back plate in contact with the heat pump are all made of aluminium with anodised surfaces. All fixings are stainless steel.

The bath is fitted with silica windows to allow the conditioning and probe beams to pass.

2. Components

The aluminium back of the bath is bolted to the heat. By removing the lid the bolts can be undone and the bath removed. The bath temperature sensor is mounted in a sealed probe suspended from the removable lid. The stirrer is also suspended from the lid, to ensure uniform water temperature.

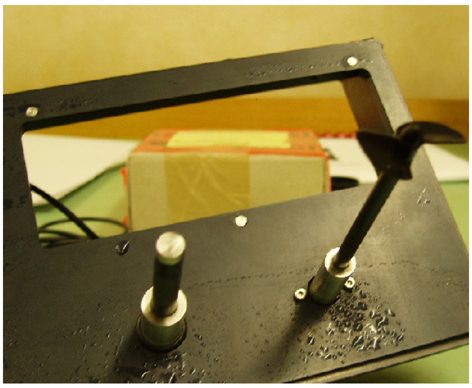


Figure18:- Temperature probe and stirrer in bath lid

The capacity of the bath is approx 1.5 litres. Please exercise attention when installing samples of large volume. The bath has been fitted with a drain (including a tap) and an overflow to prevent water overflowing from bath.

It is recommended to use distilled water, to empty the bath at the end of every day and to use fresh water.

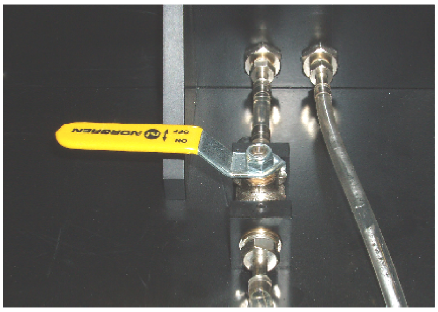


Figure 19:- Water bath tap

It is recommended to use distilled water, to empty the bath at the end of every day and to use fresh water.

Ensure that the water bath is never switched on when the bath is empty of water

T1 (°C)	T2 (°C)	Time (mins)
5	23	15
23	35	13
35	23	16
23	5	36
35	5	52

Table 4.1:- Guide temperature shift times

To aid in setting up the temperature control and as a monitor a temperature probe is provided. This has its' own holder for the sample chamber, but can be placed in one of the sample holders also.

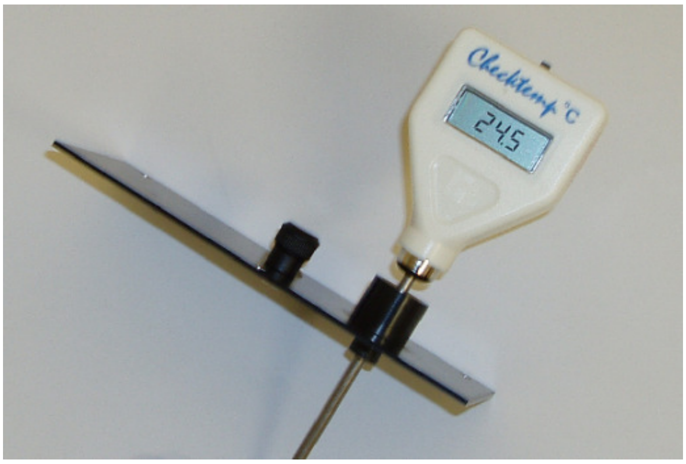


Figure 20:- Independent temperature probe

9.3.3 SAMPLE HOLDER

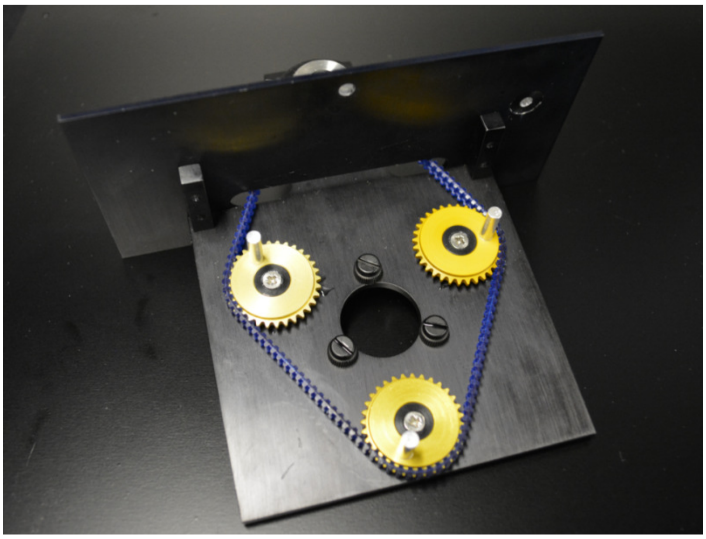


Figure 21:- Sample holder

A single sample holder is provided. Unlocking the upper thumb screw allow rotating the pins of the clamp assemble to ensure the sample is well maintained in place.

The photochromic side of the sample should rest on the plastic central screws and the upper wheel rotated to bring the lower wheel pins to clamp the sample in place. The position can be held by tightening the silver nut on the upper wheel.

9.3.4 HEAT PUMP

The heat pump is composed of a Peltier assembly housed in a heat transfer block and attached to the rear side of the water bath.

The warm side is fitted with a thermostat, above a given temperature the rear fans are activated to cool the hot side. This is particularly the case when going to lower temperatures, when the whole rear panel may become warm.

The software receives feedback from the temperature probe in the bath and adjusts the Peltier current (magnitude and sign) accordingly.

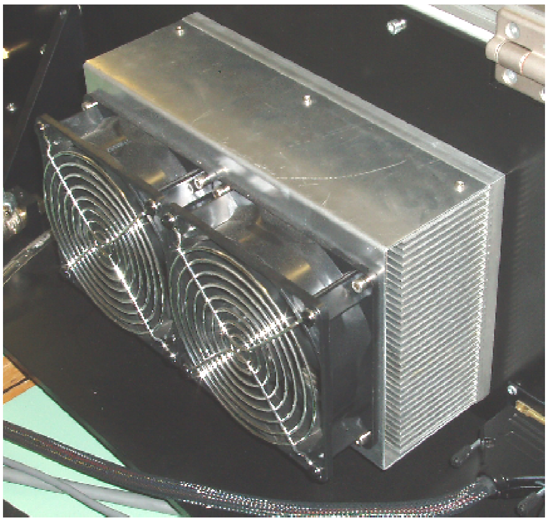


Figure 22:- Heat pump warm side fans

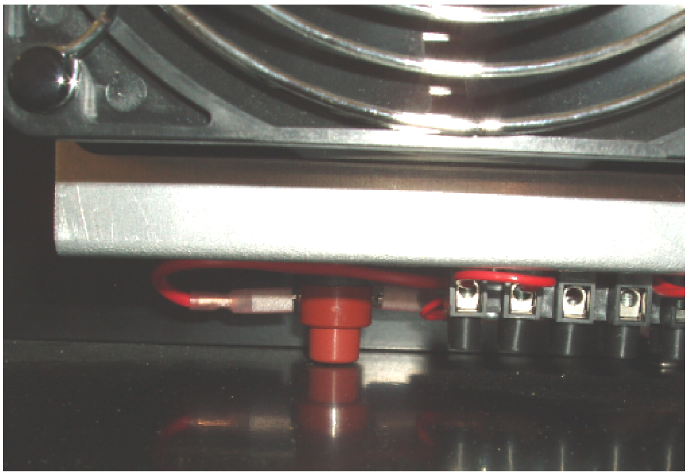


Figure 22:- Heat pump warm-side cut off

9.3.4 DUAL PATH CONFIGURATION

For speed of measurement, there exists two optical paths through the water bath, one through the sample position, the other through a position which misses the sample. In this way, the relative spectral difference between the two paths can be determined, and in measurement, it need not be necessary to remove the sample to perform 100%, reference measurements.

This dual path configuration is realised by the use of computer controlled swing away mirrors (SAMs) as seen in the following.

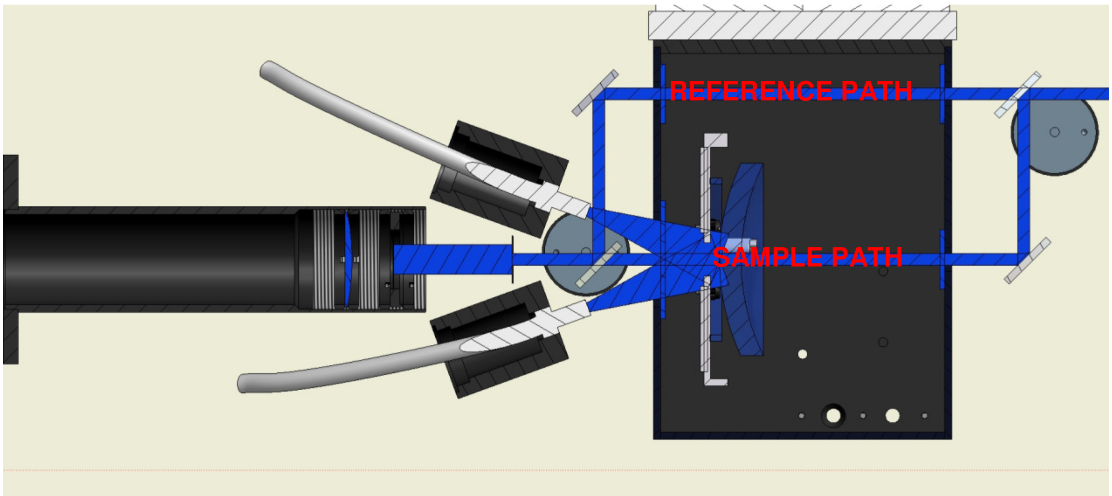


Figure 23: Dual Path Configuration

9.4 DETECTORS AND DETECTION ELECTRONICS

9.4.1 DETECTOR STATION

The detectors of this system are a side- window bi-alkali photomultiplier tube (PMT) (200-~650nm and a silicon detector (250- 1100nm). In this system it is recommended to operate the PMT over 280-380nm and the silicon detector over the range 380-780nm.

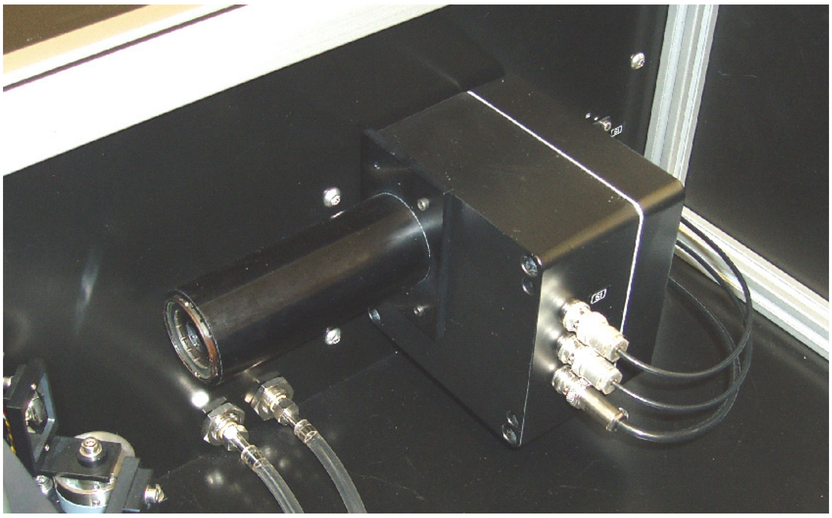


Figure24:- Detector station

These detectors are operated in the AC regime and are configured in the following manner, the Silicon detector is position at 45° to the incoming beam from sample chamber, light reflected from this detector incident on the PMT, fitted with UG11 UV band-pass, and ND2 filters.

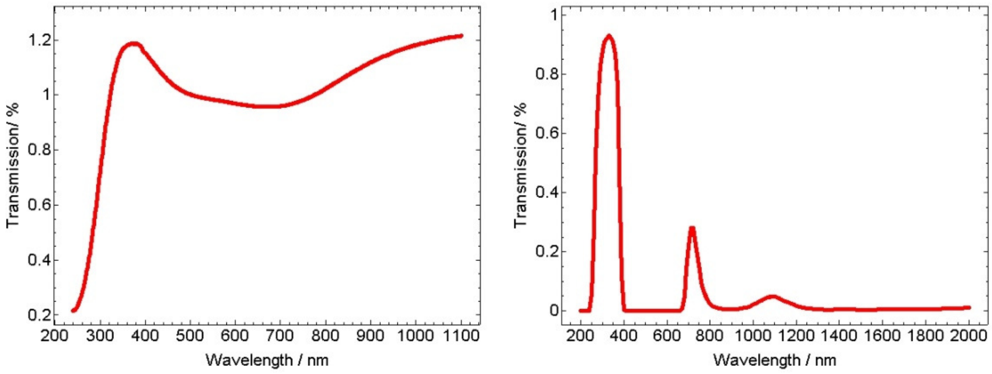


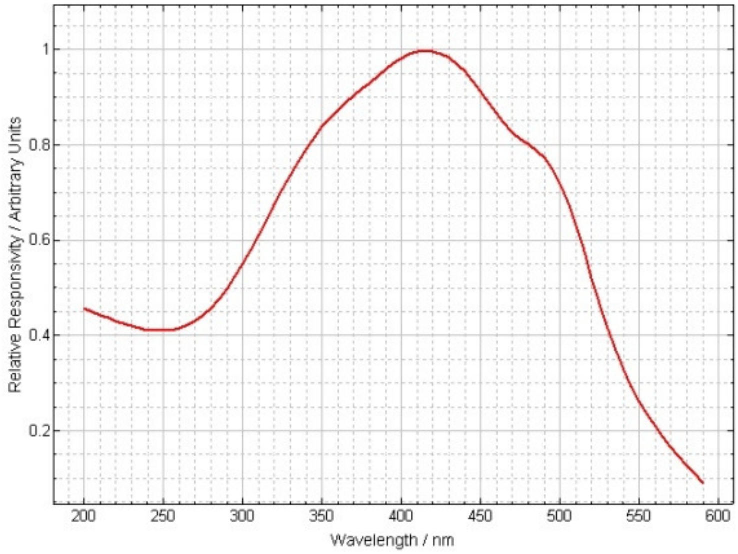
Figure 25:- (left) ND2 filter and (right) UG11 filter transmission

The bi-alkali PMT is included to cover merely the UV region, and, being particularly sensitive is configured to see only the light reflected from the front surface of the silicon detector, and filtered by a neutral density (ND2) filter and a UV band-pass filter (UG11).

The PMT comprises a photocathode, 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 and 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 required high voltage is supplied by the 215 module, set to 650V.



Figures 25:- Bi-alkali PMT typical relative responsivity

The appropriate sockets are labelled on the PMT housing. Electrical connections for the signal is always via narrow BNC cable, the high voltage thicker BNC having an insert in the connector to avoid wrong connections. The signal output should go to the current amplifier 477 input 1.

A 10 x 10mm silicon detector is used to cover the range 380-780nm. This detector has a sole connection which goes to the current amplifier input 2.

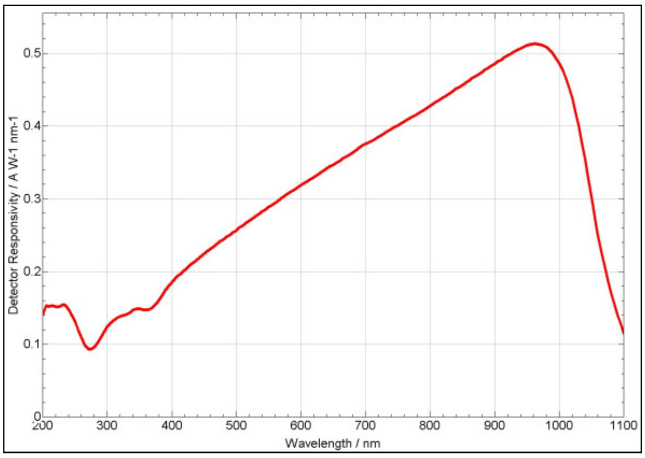


Figure 26:- Silicon detector typical responsivity

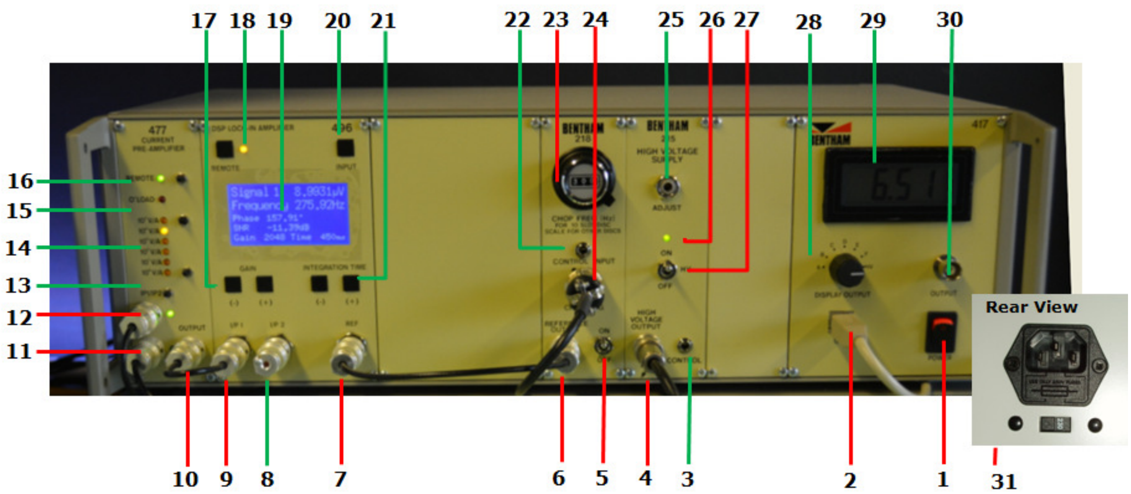
9.4.2 417 UNIT DETECTION ELECTRONICS

The 417 unit provides power to and houses the various Bentham detection electronic modules of a system.

The operating voltage of the 417 has been set up at Bentham according to where the device is sent, as indicated by a toggle selector, found underneath the mains connector, and an appropriate fuse (plus a supplement) fitted (220V- 630mA anti-surge/ 110V – 1260mA anti-surge).

In the FSL300 system, the LCD display, rotary channel-selector switch and BNC channel analogue output are used only to view the high voltage setting of the 215 module, where the value in the display is one hundredth of the true value. Please not that the BNC output does not provide a HV signal, but the same reduced value.

The detection electronics suite of the FSL300 system comprises a 417 unit fitted with a 477 current pre-amplifier, 496 DSP lock-in amplifier, 218 optical chopper controller, 215 high voltage supply and 2CPS1M dual output Peltier cooler controller.



1	Mains switch	**17**	496 gain range selector
2	USB input	**18**	496 local use/ remote indicator
3	215 External control input	**19**	496 LCD
4	215 High voltage output	**20**	496 input selector
5	218 Chopper on-off switch	**21**	496 integration time selector
6	218 Chopper reference output	**22**	218 Control input
7	496 reference input	**23**	218 Frequency selector
8	496 input 2	**24**	218 Chopper Output
9	496 input 1	**25**	215 High voltage adjustment
10	477 output	**26**	215 HV status indicator
11	477 input 2	**27**	215 on-off switch
12	477 input 1	**28**	417 Display channel selector

13	477 input selector & LEDs	**29**	417 LCD display
14	477 Gain range selector & LEDs	**30**	417 Channel analogue output
15	477 overload indication	**31**	Mains toggle switch
16	477 local use/ remote indicator		

Figure 27 8: 417 Unit and detection electronics

9.4.3 477 AC CURRENT PRE-AMPLIFIER

The 477 is used as a pre-amplifier for a lock-in amplifier in AC systems employing current source detectors such as photomultipliers and photodiodes (eg. Si, Ge, InGaAs, InSb) which, at low frequencies, give their best performance when connected to a virtual ground. The 477 provide six decades of signal gain.

he two virtual earth inputs of the amplifier ensure that the detector is kept in short circuit condition, whereby no voltage is generated across the detector as a result of the photocurrent it produces. This short circuit operation enhances the linearity of detectors, reduces the effect of cable capacitance and is often a necessary condition in the determination of detector responsivity.

In the BPC300 system, the output of the 477 amplifier should be connected to input 1 of the 496 DSP lock-in amplifier. To input one should be connected the PMT and input 2 the silicon photodiode.

Please see section 9.5 for software control.

Please see separate 477 manual for further details on this unit.

9.4.4 496 DSP LOCK-IN AMPLIFIER

The 496 lock-in amplifier is a key component of spectroradiometer systems operating in conditions where the optical signal to be measured may be confounded with a background optical signal, whether from ambient lighting, or, in the infrared, heat (or infrared radiation) emitted by instrumentation and the background.

To discriminate the two contributions, the optical signal to be measured is modulated on a known carrier wave by an optical chopper, the relative phase difference between these two waveforms must be taken account of. In the 496, the input and reference are digitised prior to determination of the components in two orthogonal states in order to take the vector sum of the two. Phasing intervention as is custom with traditional lock-in amplifier-based systems, is therefore not required.

In the BPC300 system, the output of the 477 amplifier should be connected to input 1 whilst the reference output of the optical chopper should be connected to the ref port.

Please see section 9.5for software control.

Please see separate 496 manual for further details on this unit.

9.4.5 218 CHOPPER CONTROLLER

The optical chopper is controlled by the 218 unit.

The dial shows the chopping frequency for a ten-slot chopper blade, and can be locked and unlocked by a small tab underneath the dial. The value should be scaled according to the blade fitted to a particular system.

The chopper used has a five slot blade, one should multiply the 218 dial frequency by two. It is recommended to operate the BPC300 system at either 175 or 225 Hz (in any case, avoid a multiple of the 50Hz line frequency).

Connection between the controller and the chopper is by an amphenol socket connector. This provides power to the chopper motor, and returns to the 218 module a reference signal derived from an optical sensor (IR emitter-receiver) on the chopper. Ensure that the reference output of the 218 is connected to the 496 DSP reference in port.

Please see separate 218 manual for further details on this unit.

9.4.6 215 HIGH VOLTAGE SUPPLY

The PMT is operated in the photoemissive mode, and requires a high voltage to operate the electron gain section.

The 215 has been set in factory to 650V DC, there is no need to modify this value. This setting can be verified by setting the rotary switch of the 417 to HV. The voltage reported in the LCD is one hundredth of the HV applied.

Please see separate 215 manual for further details on this unit.

9.5 BENWIN+

9.5.1 OVERVIEW

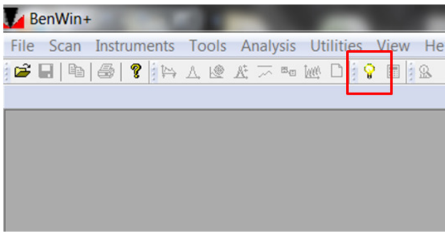
Benwin+ is a Windows software designed to control Bentham's range of monochromators, detection electronics and accessories. To establish communication with hardware, it is directed to an xml configuration file which describes the elements of hardware to be controlled and their properties (USB address grating parameters and calibration values etc.). There exists only one such configuration in the BPC300 system.

9.5.2 RUNNING BENWIN+

1 Ensure that the TMc300, PMC MAC (2 USB connections) and 417 are connected to USB and powered on.

Run Benwin+ from desktop icon.

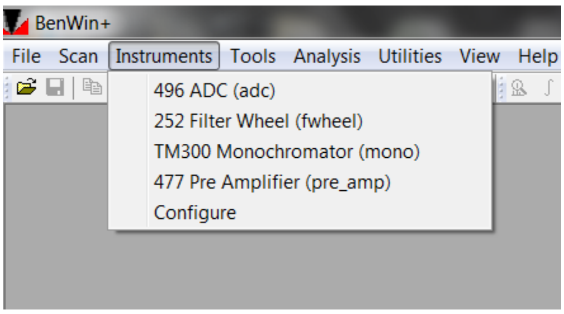
2 Hit the light bulb icon to initialise the system. You will hear motors in the TMc300 as the turret and filter wheel are sent to their reference (park) positions.



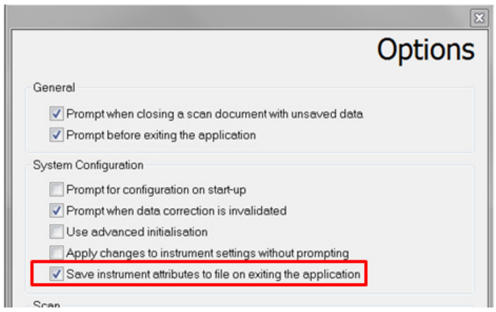
3 The system is now ready for use.

9.5.3 INSTRUMENT ATTRIBUTES

The instruments menu lists the system components, giving access to their properties, which are all saved in the xml file. Any changes to these values are saved on closing Benwin+.



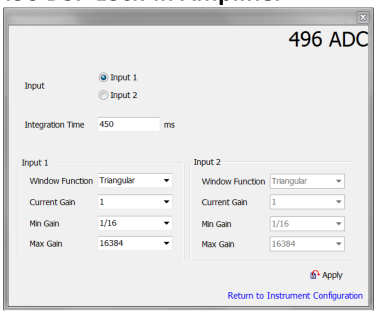
This default can be removed by going to tools/ options and de-selecting “save instrument attributes to file on exiting the application”. Hit apply.



Should any problems be encountered in use of the system (for example if the settings have been changed), simply overwrite the existing xml file in c:\public documents/Bentham/Benwin+\configurations with that in the Benwin+ CD BenWin+\Public Documents\Configurations folder.

Benwin+ measured results saved as .ben files in c:\public documents/Bentham/Benwin+\spectra folder. The format of these files is binary. One can however export data to Excel.

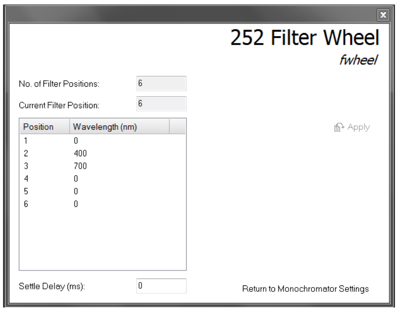
496 DSP Lock-In Amplifier



Input Selection: Select input in use, input 1 here.
Integration time: Define integration time of ADC, 450ms typical (min 10ms, max 32s).
Window Function: Rectangular, sin, Hann triangular window functions used to deal with noise (Sin standard).
Current Gain: Target range to commence measurements, range 1 typical.
Min & Max Gain: Recommend to use all ranges, 1/16 to 16384.

These values may be changed by the user.

252 Filter Wheel

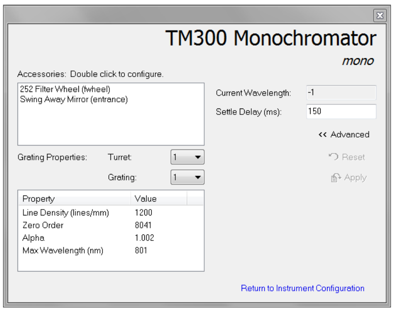


The filter wheel has six positions, fitted with filters described in Table XXX and are specified here by their wavelength of insertion.

The 2000ms settle delay is the wait time applied following each movement of the filter wheel.

⚠ **Do not change these values**

TMc300 Monochromator

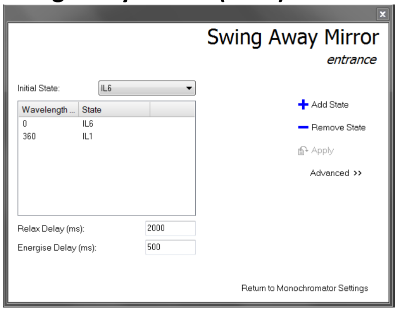


The advanced button on this page gives access to the parameters of the gratings in the monochromator, pull-down menu permits toggling between turrets and gratings.

The zord and alpha measurements are obtained from the calibration certificate.
The 150ms settle delay is the wait time applied following each movement of the monochromator.

Do not change these values

Swing Away Mirror (SAM)

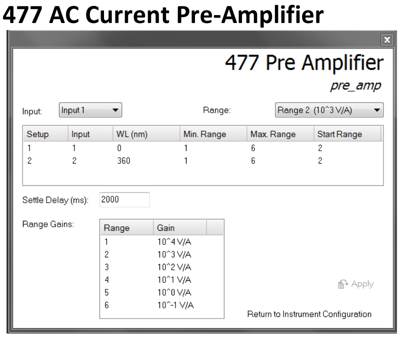


This page is accessed via a link in the monochromator page and defines states of the SAM as a function of wavelength.

The 5000/500ms settle delay is the wait time applied following each movement of the SAM- longer when de-energised.

Do not change these values

477 AC Current Pre-Amplifier

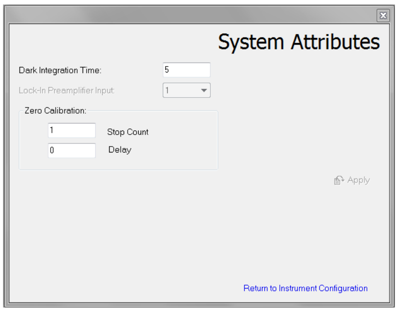


All ranges are used, it is recommended to use range 1 as the start range.

Settle delay of 1000ms is sufficient.
The 2000ms settle delay is the wait time applied following each gain range change of the amplifier.

Do not change these values

Miscellaneous



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

Do not change these values

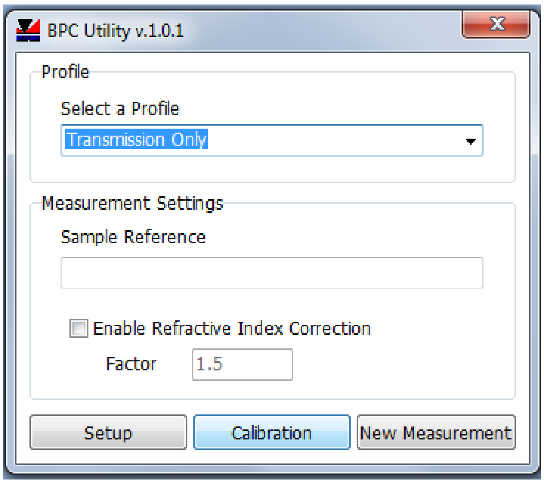
Please see separate Benwin+ manual for further details on software functions.

9.5.4 BPCUTILITY

All measurements in Benwin+ with the BPC300 are driven from this utility, accessed from the utilities menu.

The following describes the many features of this utility.

Running the BPCUtility leads to the screen over.



Select a profile: One can select a previously generated profile with a view to performing measurements.

The system has been supplied with two profiles, transmission only and ISO 8980-3:2013 Standard.

Measurement settings: Provide reference name for sample

Enable refractive index correction: Input known refractive index of sample to correct results, measured in water to obtain those in air

Setup: Described below

Calibration: Described below

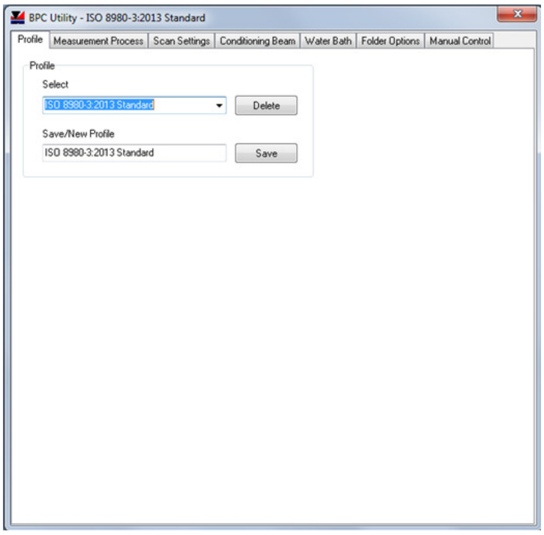
New Measurement: Launch measurement sequence defined by selected profile

Setup Window

Selecting setup leads one to the set up window having a number of tabs/

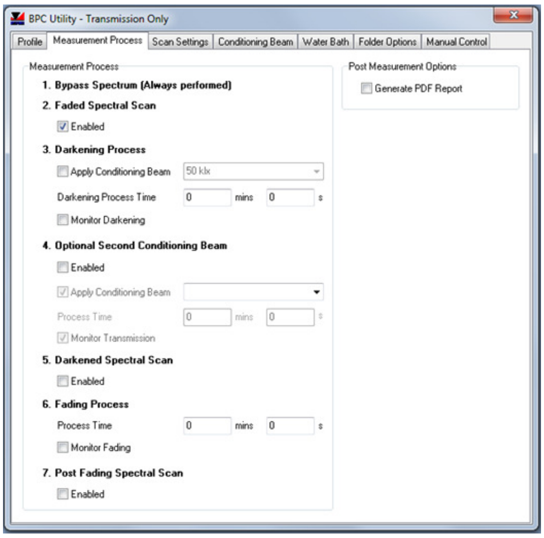
Profile:

This page allows loading of existing profiles through the select tab, or the generation of new profiles, setting the required parameters and providing a suitable name before hitting save.



Measurement Process:

This page allows definition of the measurement process to be conducted and to select whether a report is required or not.



Bypass measurement. Measurement performed of second (sample free) path for 100% reference measurement.

Faded spectra scan. Check to perform scan prior to darkening.

Darkening Process. Check to apply conditioning beam and select condition from pull-down list. Input process time. Check to monitor transmission at defined wavelength during darkening.

Optional Second Conditioning Beam. Check to enable. Check to apply second conditioning beam and select condition from pull-down list. Input process time. Check to monitor transmission during process.

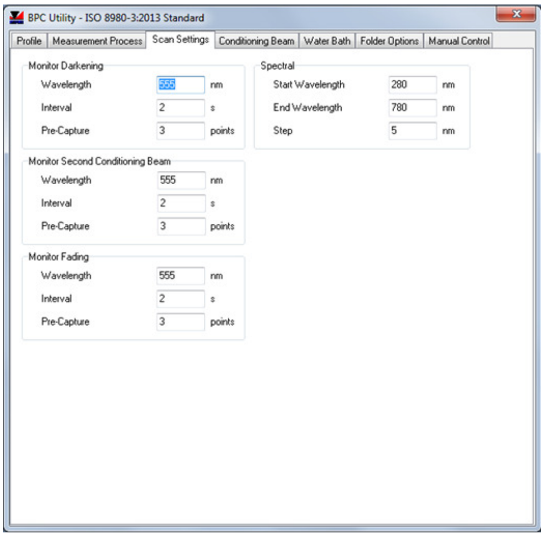
Darkened Spectral Scan. Check to enable to perform transmission measurement in darkened state.

Fading Process. Where required define period of time over which transmission monitored in fade-back

Post Fading Spectral Scan. Check to enable spectral scan at given time after end of darkening process.

Scan Settings:

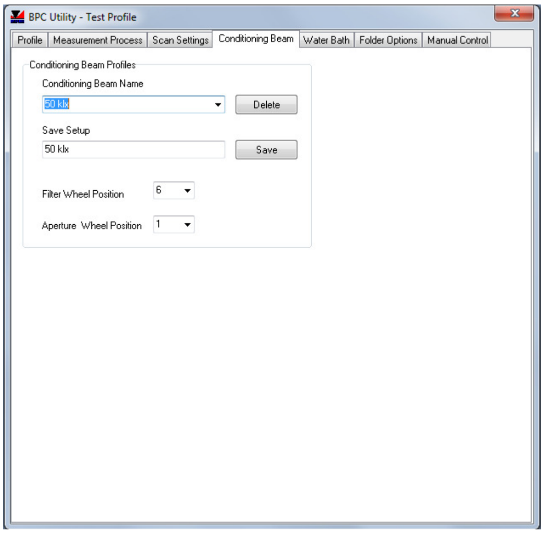
In this page one can define the spectral range over which measurements are to be performed (280-780nm, required by standards). Given that the BPC300 is setup with a 5nm bandwidth, 5nm step is recommended.



One can also define the conditions of the transmission monitoring during conditioning and fading back-select wavelength, data points interval (2s recommended) and pre-capture (recommended 3 points), the number of data points take before the change in state of the conditioning beam.

Conditioning Beam:

One can define the aperture and filter wheel configuration appropriate for a given conditioning beam configuration. Currently only two are defined, 50 klx and 15klx, no filters being used.

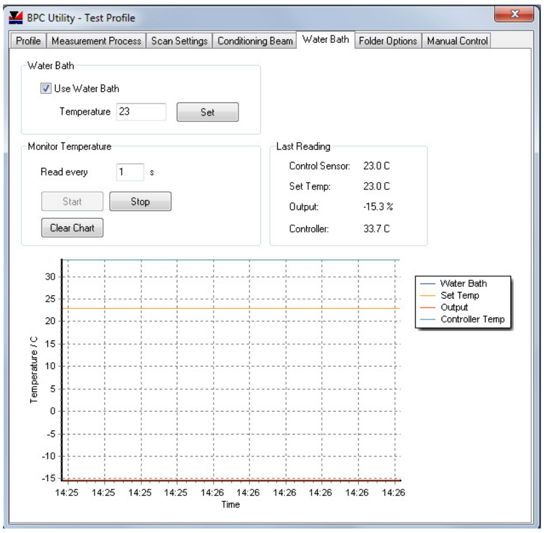


Water Bath:

Check to enable use of water bath, at defined temperature (23°C standard, low temperature 5°C and high 35°C).

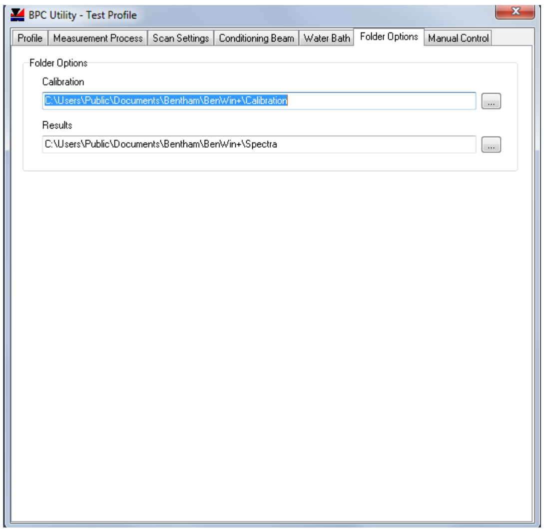
Hit set to activate temperature control live.

To view temperature control status, one can define a temperature monitor read time and start the process. The water bath temperature, controller temperature and the Peltier cooler output will be reported in the graphic.



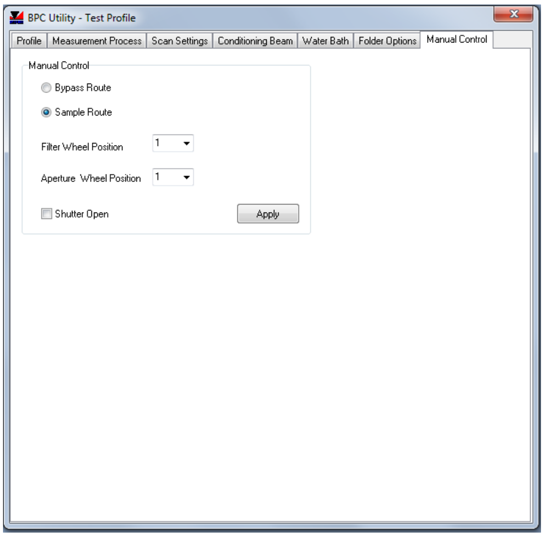
Folder Options:

One can define the default location for calibration (path ratio files) and measurement results.



Manual Control:

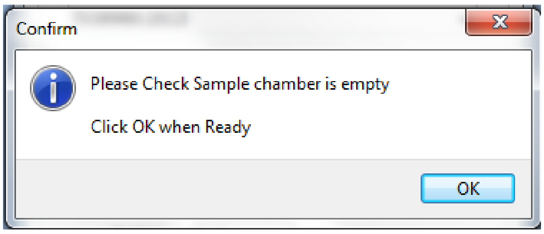
This mode is used in system setup to independently select status of various elements.



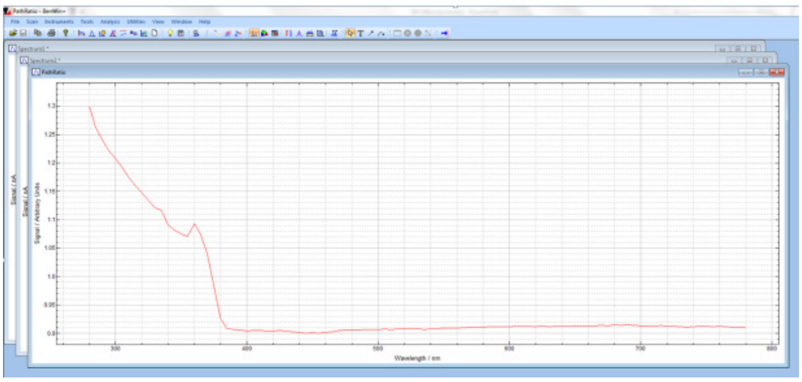
Calibration

This procedure measures both paths of the dual configuration (bypass and sample routes) to allow generation of a path ratio file which will correct all future reference measurements.

On hitting this button the user will be prompted to ensure that the bath is empty (but must be filled with water).



Two measurements will be performed, through both paths and the ration calculated and saved.



In future measurements, at the beginning of the process a by-pass measurement will be made, to which will be applied this path ratio.

9.5.5 USE OF BENWIN+ ON DESKTOP COMPUTERS

It is possible to install Benwin+ on a desktop computer to view measurement results out of the laboratory, the initialisation procedure will of course not work.

10 EVALUATION OF PHOTOCHROMIC LENS TRANSMISSION

10.1 MEASUREMENT OVERVIEW

In order to evaluate a photochromic sample to ISO 8980-3: 2013 and ISO 12312-1:2013 (test methods applicable to ISO 12312-1:2013), after specific conditioning, the transmission of the sample,. 280-780nm should be measured prior to and after exposure to an AM2 simulator at 50 klx and the sample maintained at 23°C. Where specific claims are made with regards low or high temperature performance or for night driving different measurement conditions are required. Correction to air values should also be taken into account.

In this example, a standard measurement will performed.

10.2 MEASUREMENT PROCEDURE

1 Power on 605 power supply of conditioning beam, wait for red lamp light to extinguish indicating lamp struck.

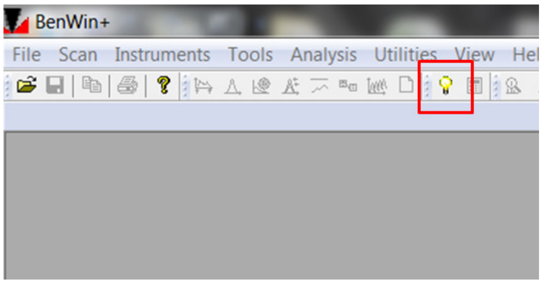
Power on remainder of system, other 605, 706, TMc300, PMC MAC and 417.

It is recommended at the beginning of the day to give the system a 15 minutes warm up period.

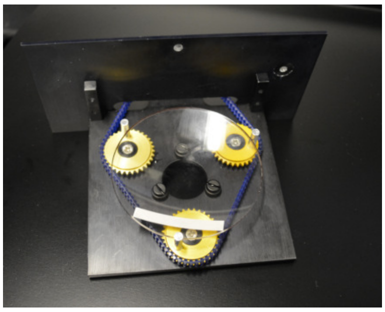
2 Ensure TMc300, 417 and PMC MAC are connected to computer by USB.

3 Run Benwin+ from desktop icon.

4 Hit the light bulb icon to initialise the system. You will hear motors in the TMc300 as the turret and filter wheel are sent to their reference (park) positions.



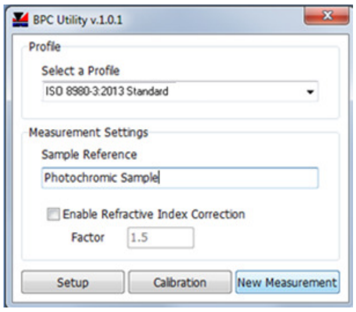
5 Mount the photochromic sample in the sample holder, photochromic face resting on plastic screws, clamp in place and insert in water bath ensuring correct orientation.



6 Go to utilities/ BPCutility.

Select ISO 8980-3:2013 Standard profile.

Input sample reference name and where known check enable refractive index correction, inputting value.



7 The measurement will proceed automatically, you will see first the measurement of the bypass route, before the transmission of the sample is measured. Fifteen minutes of exposure to the AM2 simulator follows, before a further transmission measurement.

Where required, further fading back measurements, not required by the standard, may be performed in consideration of the characteristics of the given sample.

8 At the end of the measurement procedure, a pop up box will request which pages to include in the measurement report and the pdf report generated.

All measurement results and pdf report are to be found in the defined scan location, in a folder named according to the name given to the sample.

11 TROUBLESHOOTING

The following is a list of some more common problems encountered with BPC300 system, by no means exhaustive. Please contact Bentham should any other problem arise.

Problem	Possible error/ solution
Benwin+ does not initialize	✓ Ensure all units are switched on and USB connection OK

On scanning, no signal seen	✓ Ensure detector is connected to 477 input 1 ✓ Ensure 218 is powered on ✓ Ensure lamps are powered on ✓ Ensure 215 HV is powered on
Reported transmission lower than that expected	✓ Ensure AM2 simulator set to required illuminance