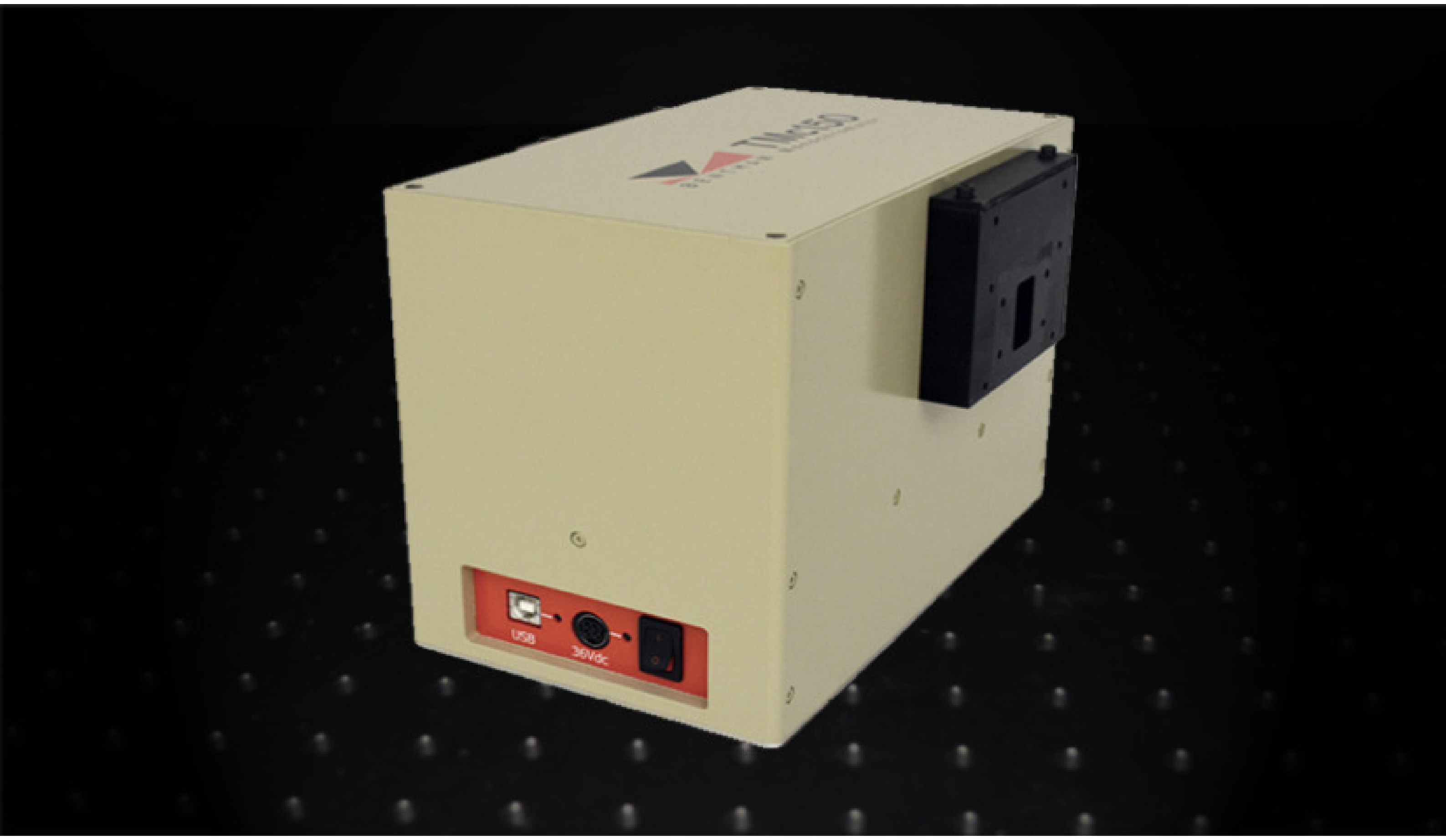
TMC150

SINGLE MONOCHROMATOR



BENTHAM

User Manual

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1 INTRODUCTION

This manual has been written to provide information on the use of the base TMc150 compact monochromator and all standard options pertaining thereto.

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.

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, please notify Bentham with full details of the problem, including model number and serial number of the instrument concerned. 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. We recommend that instruments shipped to us are fully insured and packed surrounded by at least two inches of shock-absorbing material. Specific transit packaging as used in monochromators etc. must be installed.

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 number is 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 OVERVIEW

In the TMc150 monochromator, up to 2 diffraction gratings are mounted on a turret to allow use over a wide spectral range.

For each grating there are 2 wavelength calibration parameters provided. The first is the number of steps from the datum position to 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).

The single entrance and exit ports can be fitted with either fixed, micrometer variable or motorised variable slits.

An optional 6-position order sorting filter wheel is situated behind the entrance port to suppress all but the first diffraction order. Included is a blank disk to act as a shutter.

All control electronics for the monochromator turret and internal filter wheel are situated on the underside of the unit.

Mains and the controlling USB connections are made directly to the TMc150 with the following settings, VID: 1240, PID: 5893.

Figure 1:- TMc150 monochromator

The entrance and exit slits have the following mounting hole pattern, with the centre of the slit in the centre of the hole pattern:

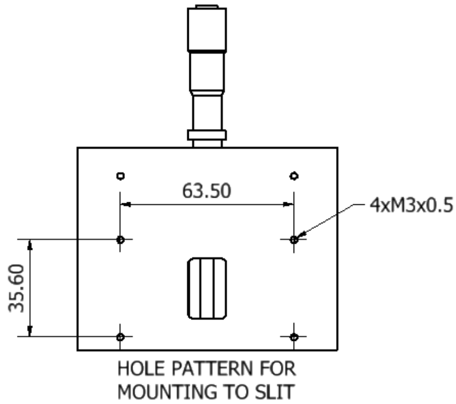


Figure 3: TMc150 slit hole pattern

6 GRATING DRIVE

In each TMc150, a turret can be found, upon which up to 2 diffraction gratings can be mounted.

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

To the turret drive is fitted a two-stage encoder, allowing the turret to be sent to a fixed datum point (negative limit). On software initialisation, the turret is sent to this position, or “parked”.

The TMc150 does not include any mechanical sine law conversion as is often the case with grating drives; each step of the stepping motor corresponds to a fixed change in angle and as a result, the wavelength change per step will vary with grating angle.

In common with all gear systems, the grating turret drive in the TMc150 suffers from backlash, a region of inaction immediately after the direction of rotation is changed, albeit reduced by the design of the drive. This is easily overcome by ensuring that the desired location of the turret (wavelength) is at all times approached from the same direction.

To go therefore from a higher to a lower wavelength, the turret should be moved beyond the target location which is then approached in the direction of increasing wavelength.

7 DIFFRACTION GRATINGS

Up to 2 diffraction gratings can be mounted to the turret of each TMc150.

The diffraction gratings for the TMc150 are 33 x 33mm, provided in a mount for attachment to the turret.

On purchasing a monochromator, all gratings are factory fitted. For those gratings purchased at a later time, further information concerning grating installation is provided in §11.

The following table summarises the maximum recommended range of use in the TMc150 of the most popular diffraction gratings offered by Bentham.

Between 0nm (at which position the grating acts as a mirror) and the minimum cited wavelength, problems may be encountered with re-diffracted light whereby the zero diffraction order is coincident with the diffraction grating, and “re-diffracted”.

Above the maximum cited wavelength, the grating is rotated to such an extent that the angle of incidence of light onto the grating will approach 90°.

Line density (g/mm)	Maximum λ Range (g/mm)
2400	200-675 nm
1800	200-900 nm
1200	300-1200 nm
830	500-1800 nm
600	800-2500 nm
400	1- 3 µm
300	1.5-5.5 µm
150	2.4-8.0 µm
100	4.5-16.2 µm
75	6- 21 µm
50	9- 27 µm

Table 1: Grating maximum range of use

8 ORDER-SORTING FILTER WHEEL

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 diffraction orders for correct measurements.

A 6- or 8-position order sorting filter wheel is to be found inside the monochromator entrance port, fitted with order sorting filters suitable for the spectral range of use.

Below 400nm, no filters are required since for the next highest diffraction order, the second, the corresponding wavelength is less than 200nm which is blocked in any case by the atmosphere.

Spectral range	Required OS Filter
<400 m	None
400-700nm	OS400
700-1250nm	OS700
1250-2000nm	OS1250
2000-3600nm	OS2000
3.6-6 µm	OS3600
6-10.5 µm	OS6000
10.5-21 µm	OS10500
> 21µm	please consult

Table 2: Required order sorting filters

A blank disk in the last position (6 or 8) stops light from entering the monochromator during dark current and offset measurements.

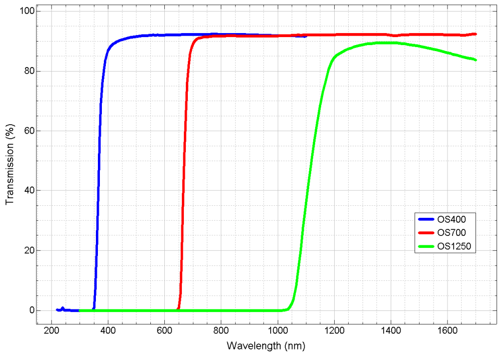


Figure 2:-Typical OS filter transmission

9 ENTRANCE & EXIT SLITS

9.1 INTRODUCTION

The entrance, exit and middle slits of the TMc150 can be fitted with either of the following assemblies: fixed, micrometer variable or motorised variable.

9.2 FIXED SLITS

Where the fixed slit option is purchased, 3 sets of slits are provided according the required system bandwidth.

Fixed slit carriers incorporate a spring leaf to push the slit against its datum face to ensure the correct placement of the slit.

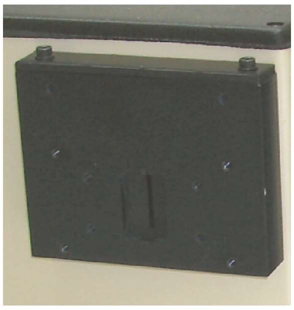


Figure 3:-Fixed slit

Changing entrance and exit slits:-

- Remove fixed slit cover with M3 Allen key
- Using pincers, pull out slit
- Place new slit in holder with etched side facing away from monochromator, flat rear of slit against the monochromator

- Push fixed slit down, firmly into place
- Replace cover

Changing middle slit:-

The same procedure as above applies, noting that the etched side should face away from the first monochromator (that having the power supply and USB interface).

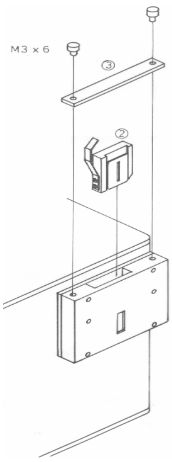


Figure 4:- Changing fixed slits

It should be noted that where a photomultiplier detector is mounted to the slit in question, the high voltage is switched off during the changing of the slit to prevent exposure to ambient lighting.

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

9.3 MICROMETER VARIABLE SLITS

Micrometer variable slits make use of a Vernier calliper controlled pair of bi-lateral slits, variable from 10µm to 10mm.

Figure 5:-Micrometer variable slit

One rotation of the calliper is equivalent to 0.5mm in slit width; the slit dimension can be read off the Vernier.

To the base of the barrel a knurled nut locks the position (clockwise). This should be undone (anti-clockwise) before changing the dimensions of the slit.

Forcing the calliper beyond the zero position can result in damaging the bi-lateral slits.

9.4 MOTORISED VARIABLE SLITS

Motorised variable slits are comprised of stepping motor-driven bi-lateral slits, driven either from the internal monochromator electronics or from an external MAC electronics bin, and are variable from 10µm to 10mm.

Figure 6:-Motorised variable slit

Each slit should be connected to the correct drive (numbered), and all cables should be firmly attached.

NEVER CONNECT OR DISCONNECT SLIT CABLES WHILST MAC ELECTRONICS/ MONOCHROMATOR POWERED ON!

The motorised slits are entirely controlled by computer through the USB interface, please see §14.

10 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 5nm, will result in the measurement of a single line.

In many instances this is of no concern, since the power measured is nevertheless 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, on 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 will 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.

Grating Groove Density (l/mm)		**2400**	**1200**	**600**	**400**	**300**	**150**	**100**	**75**	**50**
Reciprocal Dispersion (nm/mm)		**1.35**	**2.70**	**5.40**	**8.11**	**10.81**	**21.62**	**32.42**	**43.23**	**64.85**
Slit widths (mm)	**Part no. for pair of slits**	**Bandwidth produced (nm)**								
0.05	FS (0.05)	0.07	0.14	0.27	0.41	0.54	1.08	1.62	2.16	3.24
0.1	FS (0.10)	0.14	0.27	0.54	0.81	1.08	2.16	3.24	4.32	6.48
0.2	FS (0.20)	0.27	0.54	1.08	1.62	2.16	4.32	6.48	8.65	12.97
0.37	FS (0.37)	0.50	1.00	2.00	3.00	4.00	8.00	12.00	16.00	23.99
0.4	FS (0.40)	0.54	1.08	2.16	3.24	4.32	8.65	12.97	17.29	25.94
0.5	FS (0.50)	0.68	1.35	2.70	4.05	5.40	10.81	16.21	21.62	32.42
0.56	FS (0.56)	0.76	1.51	3.03	4.54	6.05	12.10	18.16	24.21	36.31
0.74	FS (0.74)	1.00	2.00	4.00	6.00	8.00	16.00	23.99	31.99	47.99
1	FS (1.00)	1.35	2.70	5.40	8.11	10.81	21.62	32.42	43.23	64.85
1.12	FS (1.12)	1.51	3.03	6.05	9.08	12.10	24.21	36.31	48.42	72.63
1.48	FS (1.48)	2.00	4.00	8.00	12.00	16.00	31.99	47.99	63.98	95.97

1.85	FS (1.85)	2.50	5.00	10.00	15.00	19.99	39.99	59.98	79.98	119.97
2	FS (2.00)	2.70	5.40	10.81	16.21	21.62	43.23	64.85	86.46	129.69
2.78	FS (2.78)	3.76	7.51	15.02	22.53	30.05	60.09	90.14	120.18	180.27
3.7	FS (3.70)	5.00	10.00	19.99	29.99	39.99	79.98	119.97	159.96	239.93
4	FS (4.00)	5.40	10.81	21.62	32.42	43.23	86.46	129.69	172.92	259.39
5.56	FS (5.56)	7.51	15.02	30.05	45.07	60.09	120.18	180.27	240.36	360.55
8	FS (8.00)	10.81	21.62	43.23	64.85	86.46	172.92	259.39	345.85	518.77
10	-	13.51	27.02	54.04	81.06	108.08	216.16	324.23	432.31	648.47

Table 4: Single configuration bandwidth

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

It is worth noting that care should be taken 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 is the exit slit to avoid any conflict with the input optic.

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.

11.1 SOFTWARE CONTROL

11.1 INTRODUCTION

The TMc150 may be controlled, as part of a Bentham spectroradiometer system, with BenWin+, or by customer-written applications based on the Bentham Instruments' SDK.

For further details on control with the SDK, please consult the SDK manual.

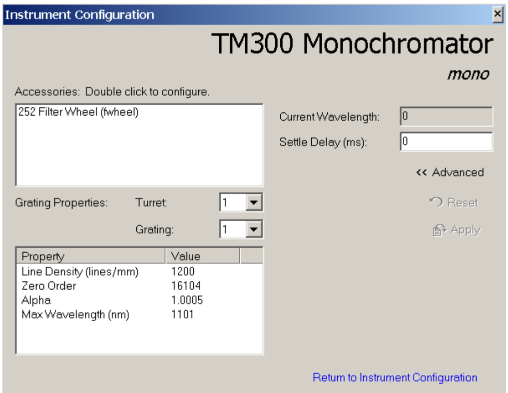
For an overview of the instrument settings in BenWin+ please see the following. For use of the software to perform spectral measurements, please consult the BenWin+ manual.

11.2 MONOCHROMATOR

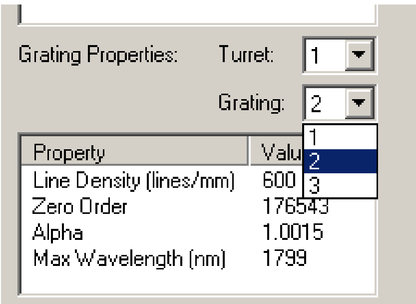
The properties of the TMc300 are obtained in the following menu item:-

Instruments/ Monochromator

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



The drop down arrow allows toggling between gratings and turrets.



The zord and alpha parameters for each grating are obtained from the calibration certificate.

The max wavelength is the selection criterion from one to another grating. This should not exceed that recommended in Table 1, but can be changed to optimise signal, for example where one grating loses efficiency another might gain (taking into account both change in efficiency and change in bandwidth as one migrates to another grating).

For USB- based systems, the settle delay can be set to 0ms. In the case of IEEE monochromators, a settle delay of 100ms is suggested.

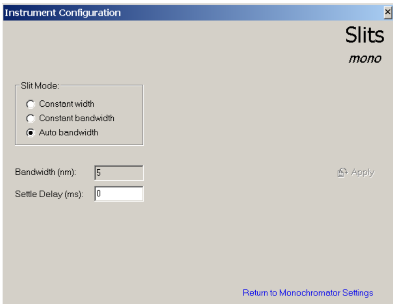
11.3 FILTER WHEEL

The properties of the filter wheel are obtained in the following menu item:-

Instruments/ Filter wheel

The insertion wavelength relevant to the filter in a given position should be input. The order need not be ascending.

A settle delay of 1000ms is sufficient.



11.4 MOTORISED SLITS

The properties of the motorised slits are obtained in the following menu item:-

Instruments/ Motorised slits

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 set-up 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.

11.5 CONFIGURATION FILES SYNTAX

Please consult the BenWin+ manual for further information concerning configuration file syntax.

12 WAVELENGTH SELECTION

The first order grating equation for the TMc150 is:

$$\lambda = 2d \, \mathrm{Sin}\theta \, \mathrm{Cos}\beta$$

Where:

λ, = wavelength (m)

d = groove spacing of the diffraction grating (m)

θ = grating angle in degrees

β = a fixed angle determined by the design of the monochromator (cosβ for the TMc150 = 0.9727)

The grating angle required for wavelength λ is therefore given by:-

$$\theta = \sin^{-1}\left(\frac{\lambda.RD.10^{-6}}{1.9454}\right)$$

Where λ is in nm, RD in grooves per mm.

The zord value given for each grating corresponds to the number of motor steps between the datum point and zero angle for that grating (at which point the grating acts as a mirror).

The Alpha value given for each grating is used to modify the calculated grating angle to give the best wavelength accuracy.

The position of the grating for a given wavelength is calculated as the number of motor steps from the datum point.

Position= (θxAlphax(500000/360))+zord

This is calculated for the turrets of both component TMc150s.

13 WAVELENGTH CALIBRATION

13.1 OVERVIEW

The TMc150 was wavelength calibrated in factory.

We recommend that the customer periodically checks the wavelength calibration, particularly if the device has been transported.

The initial wavelength calibration procedure typically consists of placing a white light source on the monochromator entrance slit and finding the number of micro steps from the park position to the zero order position (zord).

At this position, the white light is transmitted through to the exit of the monochromator. In the case of the TMc150, the first monochromator transmits the white light through the middle slit; the second through the exit slit.

This procedure represents a gross calibration; armed with the zord value one can measure a source having known line emission to refine the calibration.

To this end a mercury lamp is typically employed, which emits a number of spectral lines in the region 250-700nm, whose position never changes.

In practice, higher diffraction orders are useful when performing wavelength calibration to provide a larger number of reference points. 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 setting the insertion wavelength of the non-required filters to 0nm (in BenWin+, instruments menu/ filter wheel).

The following summarises a number of the useful 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						

Table 5: Principle Hg emission lines

13.2 SPECTRAL MEASUREMENTS

Spectral measurements are performed, the positions of these lines checked and the calibration factors, alpha and zord changed to bring the monochromator into calibration. We recommend that the customer does not change alpha however.

Where the Hg lines are too low in wavelength, the zord value should be increased and vice versa.

As a guide, for 2400g/mm in the double configuration, 100steps corresponds to ~1nm, and 50 steps in the single configuration. The dispersion of the 1200g/mm grating is half this, etc.

Measurements in step of 0.1nm (with the slits in manual bandwidth where motorised slits are used) should be made of the regions around the Hg lines, and either the peak values or FWHM central wavelength taken as the position of the line.

Be aware of the slits presently in use in the system. Having for example 5nm slits 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 there is no useful emission of the Hg source, gratings are set up with the zero-order position, setting the monochromator to 0nm and ensuring the white light is transmitted through the exit slit.

Where a mercury lamp is not available, overhead fluorescent lamps are often of use since they contain mercury gas.

Because of the glass envelope of the lamp no light is emitted below 350nm.

Where a system contains SAMs, the calibration procedure should be repeated in all ports.

13.3 TMC150 CALIBRATION

The calibration of the TMc150 is a 3 stage process, considering the first, then the second monochromators and then the ensemble.

To isolate a given component monochromator, one installs narrow entrance and exit slits on the given monochromator and no slits on the other monochromator of the pair.

The size of the slits used depend on the intended use of the systems, but typically are the smallest slits intended to be used. Both slits should be the same size.

The final check of the ensemble should be made with a middle slit at least 20% larger than the other slits.

14 SETTING MAINS VOLTAGE

The TMc150 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

15 NEW GRATING INSTALLATION

15.1 FITTING

Where a grating is purchased at a later date, it should be carefully installed by the customer using the following instructions as a guide.

DO NOT TOUCH THE GRATINGS OR MIRRORS. IF THE GRATING IS TOUCHED BY ACCIDENT, TRYING TO CLEAN IT CAN ONLY DO MORE HARM

Remove the lid of the monochromator

- Using the control computer, rotate the turret to give access to the free grating location
- Note that the grating has two attachment points, upper and lower
- Attach the grating positioned in the correct orientation and vertical

- Note the grating is asymmetric about the attachment points; the small area should be to the side of the order sorting filter

15.2 SETTING UP

Note that the upper attachment point of the grating is slotted. The angular position of the grating is checked by ensuring that the image does not move in the vertical plane as the grating is scanned.

This is easily checked by placing a white light source at the entrance slit and using the computer to rotate the grating, at the same time ensuring that either the image at the exit port or the diffracted light on the walls of the monochromator do not change in height.

If this is not the case, reset the angular position of the grating until this is so.

15.3 WAVELENGTH CALIBRATION

Follow the wavelength calibration as detailed in §9.

16 PRECAUTIONS

The following is a list of specific precautions aimed to preserve this system for good use.

- Do not touch gratings nor optics
- Do not subject monochromator to violent physical shock- this may invalidate wavelength calibration
- Do not separate component TMc150 from base plate
- Do not use over-long screws when mounting items to entrance slit for fear of damaging bi-lateral slits
- Do not let the slits bear any heavy objects
- Do not (dis)connect motorised slit cables whilst MAC electronics powered on
- Do not (dis)connect external filter wheel cable whilst MAC electronics powered on
- Follow carefully installation instructions of the external filter wheel

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