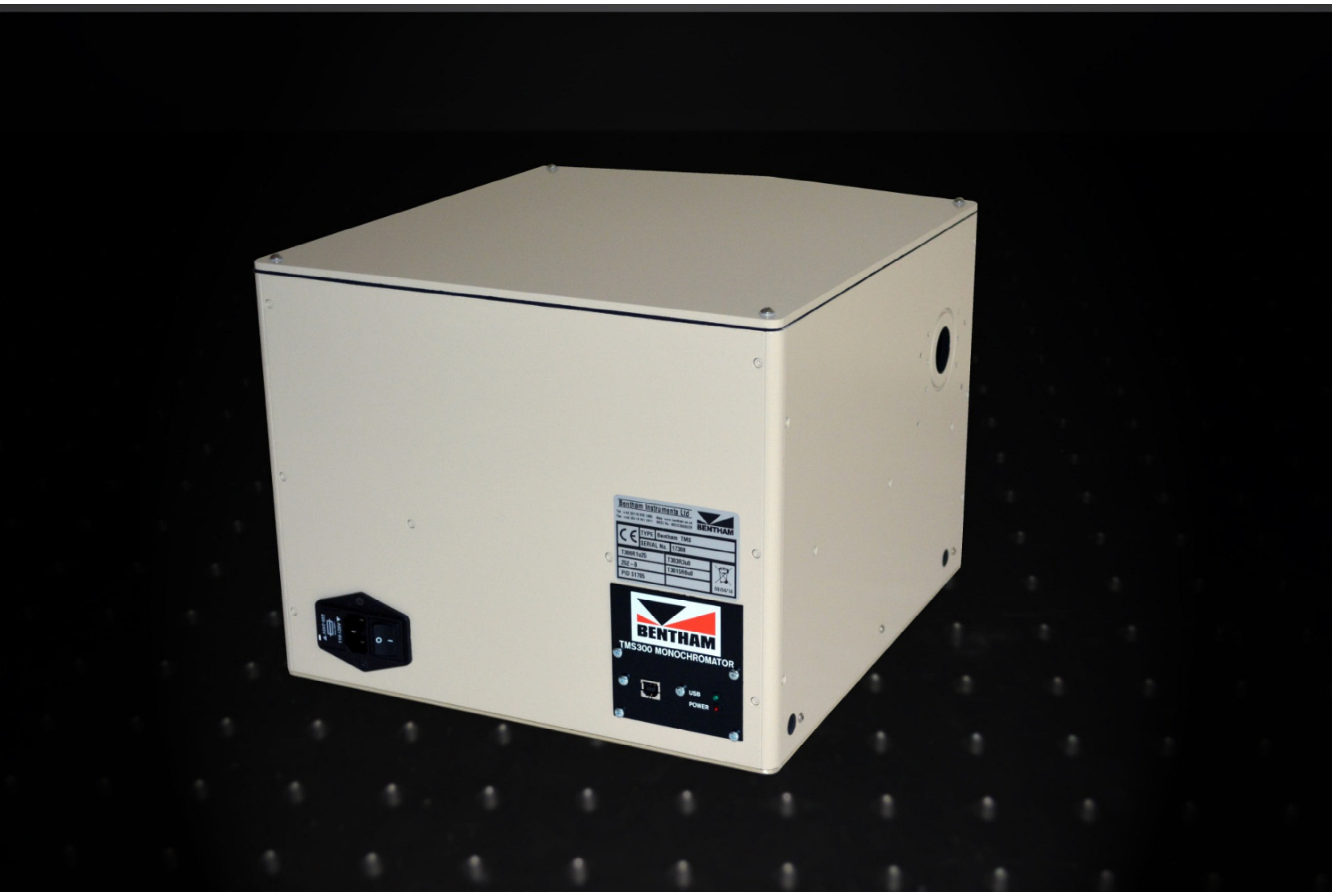
TMS300

SINGLE MONOCHROMATOR



BENTHAM

User Manual

Bentham Instruments Limited

2 Boulton Road, Reading, Berkshire, RG2 0NH, U.K.

Tel: +44 (0)118 975 1355 Fax: +44 (0)118 931 2971

Email: sales@bentham.co.uk Internet: http://support.bentham.co.uk

TABLE OF CONTENTS

1 INTRODUCTION

This manual has been written to provide information on the use of the base TMS300 single 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

Bentham Instruments Limited
2, Boulton Road
Reading
Berkshire
RG2 0NH
U.K.

sales@bentham.co.uk

http://support.bentham.co.uk

T:+44 (0)118 975 1355

5 OVERVIEW

In the TMS300 monochromator, up to 3 diffraction gratings are mounted on a turret to allow use over a wide spectral range.

For each grating is provided two wavelength calibration parameters; 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).

Multiple configurations are accommodated by the addition, at the entrance/ exit ports, of an additional slit with a computer-controlled selection mirror (SAM) between the two.

The entrance and exit ports are fitted with internally controlled motorised variable slits.

Figure 1:- TMS300 monochromator

A 6- or 8-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, internal filter wheel, motorised slits and SAMs are situated on the underside of the unit.

Mains and the controlling USB connections are made directly to the TMS300.

Further optional refinements according to application are the use of interchangeable grating turrets, external filter wheel, toroidal mirrors and a fine focus option.

6 GRATING DRIVE

In each TMS300, a turret can be found, upon which up to 3 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 TMS300 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 TMS300 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

To the turret of each TMS300 up to 3 diffraction gratings can be mounted.

The diffraction gratings for the TMS300 are 68x 84mm, 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 §18.

The following table summarises the maximum recommended range of use in the TMS300 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

5 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.

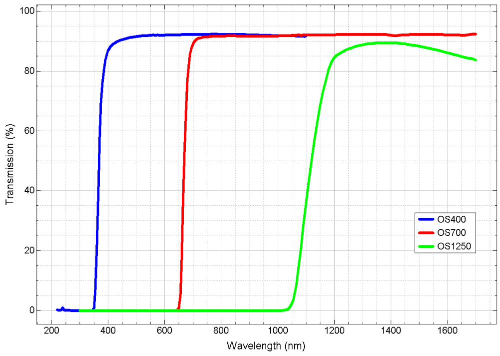


Figure 2:-Typical OS filter transmission

6 ENTRANCE & EXIT SLITS

All slits of this system are fitted with motorised variable slits, comprised of stepping motor-driven bi-lateral slits, driven from the internal monochromator electronics and variable from 10µm to 10mm.

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

7 SWING AWAY MIRRORS

Swing away mirrors allow the addition of a supplementary entrance/ exit port to the TMS300, the solenoid based mirror being set to either relay the beam from one slit or to move out of the beam to use the other.

In such a manner the TMS300 may have two entrance and two exit ports.

8 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.

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 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.

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

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.

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.

9 TOROIDAL MIRROR

A monochromator suffers from aberrations as all other optical system, albeit based on curved mirrors rather than lenses. It follows that the imaging properties of the monochromator are not perfect.

In many cases this has but little impact upon the performance of the system other than slightly degrading the system resolution.

Where a monochromator is destined for use for imaging purposes, with a CCD camera at the exit slit, it is desirable to minimise these effects.

To this end the collimator and camera mirrors of the monochromator, typically spherical, are replaced by toroidal (elliptical paraboloid) mirrors which can image better those contributions off the optical axis.

10 FINE FOCUS

The fine focus option places the camera mirror on a manually translatable stage.

This is required where a system should have the capability for use with a standard slit and with a camera, in order to move the system focal plane to a position coincident with the slit or the camera.

11 INTERCHANGEABLE TURRET

11.1 INTRODUCTION

Where a system is to be used over exceptionally wide spectral range, requiring more than 3 diffraction gratings, interchangeable turrets are employed; the stepping motor in this case drives a platform to which the grating assembly is attached.

DO NOT TOUCH OR SCRATCH THE DIFFRACTION GRATINGS. IF YOU DO SO, DO NOT ATTEMPT TO CLEAN THEM-YOU CAN ONLY MAKE THINGS WORSE.

These turrets are installed in the monochromators by the following procedure.

11.2 TURRET INSTALLATION

- Remove the lid of the monochromator with an M3 Allen key
- The turrets are housed in protective boxes
- Remove the butterfly nut and lift the turret clear of the box
- To prepare a turret for fitting it is first necessary to remove the grating covers.
- We recommend holding the cover in place over the grating (without slipping) whilst removing the two holding screws, and then gently removing the cover by holding it by the edges

The turret having a certain park position, and the wavelength calibration of the gratings referring to this point, it is essential that the turret is placed in the correct angular orientation.

To ensure this, notice that on the turret base in the monochromator there are 3 etched pits, and equally on the interchangeable turret base, there are 3 projecting screws to locate the turret.

The turret should be placed on the platform such that the ref pin (reference pin) on the base corresponds with that of the turret.

Figure 7:- Turret base showing reference pin and screw attachment

Once this is in place, insert the long attachment pin through the centre of the turret ensuring that the spring is fitted, screw this all the way down to the turret platform until finger tight, see below.

Remember to change parameters in the control software to acknowledge change of gratings. The system is now ready.

To replace the covers on the gratings, gently place the cover over the grating ensuring not to scratch the grating, attach the two screws and store in boxes provided.

Figure 8:- Long pin screwed by hand until finger tight

12 SOFTWARE CONTROL

12.1 INTRODUCTION

The TMS300 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 of control with the SDK, please consult the SDK manual.

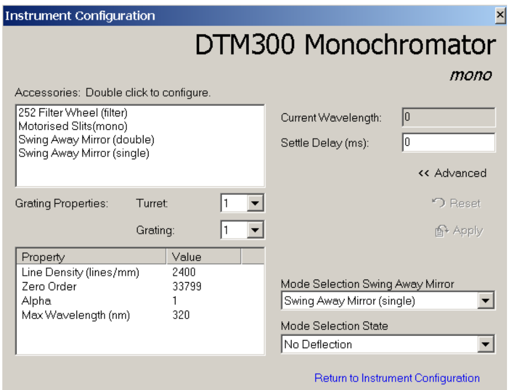
For an overview of the instrument settings in BenWin+ please see the following. For use of the software to perform spectral measurements, please consult the BenWin+ manual.

12.2 MONOCHROMATOR

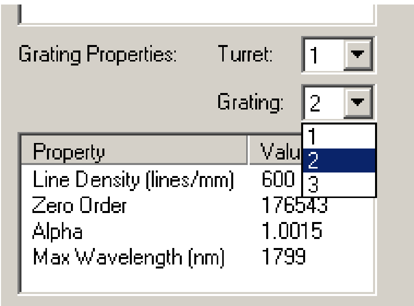
The properties of the TMS300 are obtained in the following menu item:-

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.



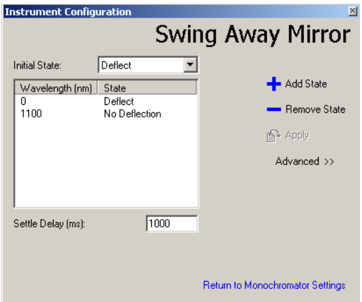
The zord and alpha parameters for each grating are obtained from the calibration certificate.

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.

12.3 SWING AWAY MIRROR (SAM)

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



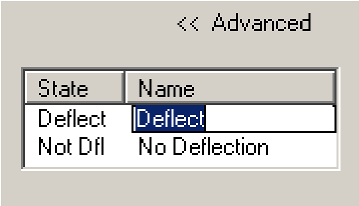
Here, one might add (“+”) a number of states (or remove by highlighting and hitting “–“).

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

SAM states are as follows:-

- Deflect- deviate light from current path
- No deflection- move out of beam

In *Advanced>>* we can name the two SAM states for easier setting up.

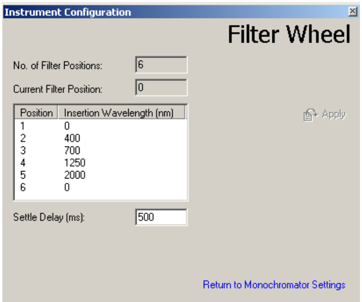


Settle delay of 1000ms is sufficient.

12.4 FILTER WHEEL

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

Instruments/ Filter wheel



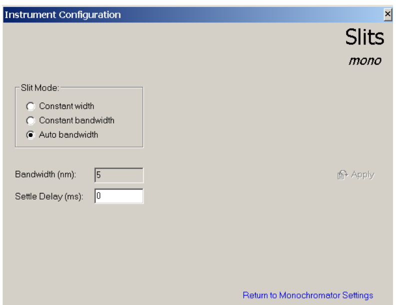
The insertion wavelength relevant to the filter in a given position should be input. The order need not be ascending.

A settle delay of 1000ms is sufficient.

12.5 MOTORISED SLITS

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

Instruments/ Motorised slits



There are 3 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.

12.6 Configuration Files Syntax

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

13 WAVELENGTH SELECTION

The first order grating equation for the TMS300 is:

$$\lambda = 2d \, \sin\theta \, \cos\beta$$

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 TMS300 = 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.

$$\text{Position} = (\theta \times \text{Alpha} \times (500000/360)) + \text{zord}$$

This is calculated for the turrets of both component TMS300s.

14 WAVELENGTH CALIBRATION

14.1 OVERVIEW

The TMS300 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.

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

14.2 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.

14.3 TMS300 CALIBRATION

The calibration of the TMS300 should be performed with the smallest slits width intended to be used, with the motorise6d slits operated in manual bandwidth mode.

Measurements should be made of a mercury source and the zord value modified to bring the device into calibration.

15 SETTING MAINS VOLTAGE

The TMS300 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

16 NEW GRATING INSTALLATION

16.1 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

16.2 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.

16.3 WAVELENGTH CALIBRATION

Follow the wavelength calibration as detailed in §14.

17 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 TMS300 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