BENTHAM

The Light Measurement Company

SSM150Xe
Tuneable
Light Source

User Manual

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Contents

1. Introduction

This manual has been written to provide information on the use of the SSM150Xe programmable monochromatic light source.

Warning

The gas contained inside the lamp is held under high pressure. Always wear eye protection when lamp exposed and hand protection when changing lamp.

The lamp in the SSM150Xe can be operated horizontally (as it is in its normal orientation), or vertically with anode uppermost; running the lamp vertically with cathode uppermost will permanently damage the lamp and lead to failure within a few hours. The following picture shows the orientation which MUST NOT be used.

2. Overview

The SSM150Xe is a tuneable light source operating over a wavelength range of 260nm to 800nm.

This bench or rack mounted unit contains a 75W xenon light source with a precision regulated supply, a concave diffraction grating monochromator and optics to couple the monochromatic output to a light guide.

The diffraction grating is mounted on a stepping motor allowing switching between wavelengths (typically < 10ms for a 100nm step).

The use of an elliptical reflector results in particularly high output power

A five position filter wheel is located at the output to suppress the presence of higher diffraction orders.

The SSM150Xe is controlled via the USB interface.

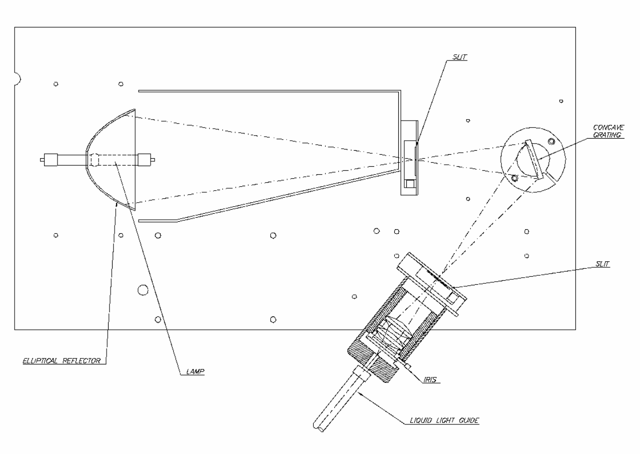


Figure 1: Layout of SSM150Xe

3. Diffraction grating

This system is fitted with a 1200 g/mm rule concave diffraction grating used over the range 250- 950nm.

4. Order sorting filter wheel

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

An order sorting filter wheel is to be found on the inside of the monochromator exit port. The following filters are fitted:-

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

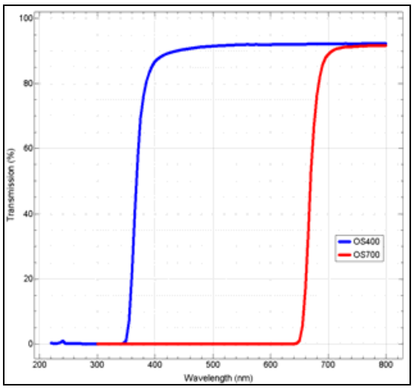


Figure 2:- Typical OS filter transmission

5. Bandwidth.

The bandwidth is set by fixed width entrance and exit slits.

Always use slits in equal width pairs.

To change slits, disconnect the unit from the mains and remove the top cover by undoing the M4 screws at the rear corners.

Pull out the slits with a pliers and replace as required noting correct orientation.

Slit Width (mm)	Nominal Bandwidth (nm)
1	6
2	12
3.7	20
8	40

6. Specifications

Wavelength range	~260nm to 800nm
Wavelength switching speed	< 10ms for a 100nm step
Wavelength accuracy	± 1nm

Furthermore, the spectral output of the SSM has been measured at Bentham, using a double monochromator, at a number of points over the spectral range 250-800nm. The absolute power output has been determined by measuring the output against a detector of known spectral responsivity.

7. Software Control

The SSM150Xe can be controlled using the Bentham Instruments USB Instruments SDK. The SDK contains standard windows DLL that can be used with a variety of different program languages. For more information about how to use the DLL please consult the USB Instruments SDK Manual.

Please Note the address for the SSM150Xe is 128. This is needed when using SDK command like "BI_USB_SEND"

To control the SSM150Xe using the SDK there are 3 main commands. These are "AutoMove" , "GratingMove" and "FilterMove". A brief description and example of each follows:

PARK
This command must be called once when the unit is powered on and before any other calls are made.
An example would be:

BI_USB_SEND(5892 , 128 , 'Park');

This command will drive both motors to there reference points, take a datum position and set all the current running speeds that will be used when the unit is moving to a wavelength.

AUTOMOVE
This command allows the programmer to control the unit with a single command.
An example would be:

BI_USB_SEND(5892 , 128 , 'AutoMove:500');

In the above example 500nm would be passed to the SSM150Xe and then the unit will decided based on internally stored calibration data how to position both the grating and the filter. In most case the filter wheel is populated with OS 400 and OS 700 filters so in this case the unit would select the OS400 filter.

GRATINGMOVE

This command allows the programmer to control just the grating in the SSM150Xe independently from Filter wheel.
An example would be:

BI_USB_SEND(5892 , 128 , 'GratingMove:500');

In the above example the unit would position the grating for the 500nm required but the filter wheel will remain unchanged.

FILTERMOVE
This command allows the programmer to select which filter position is to be used.
An example would be:

BI_USB_SEND(5892 , 128 , 'FilterMove:0');

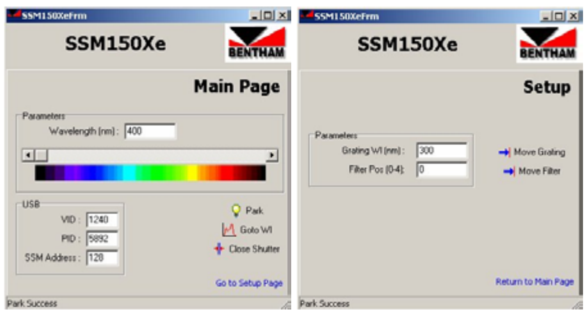
In the above example the unit would position the filter so that position 0 is in line with the output optic.

The Filter wheel in the SSM150Xe has 5 positions as described in section 2.

Furthermore, an example program is found on the USB instruments SDK CD, in the Extras folder.

This can be used to set the wavelength of the SSM150Xe, in which case both grating and filter wheel are controlled.

Each element may be controlled separately, where required, using the setup window.



Figures 4:- Example program

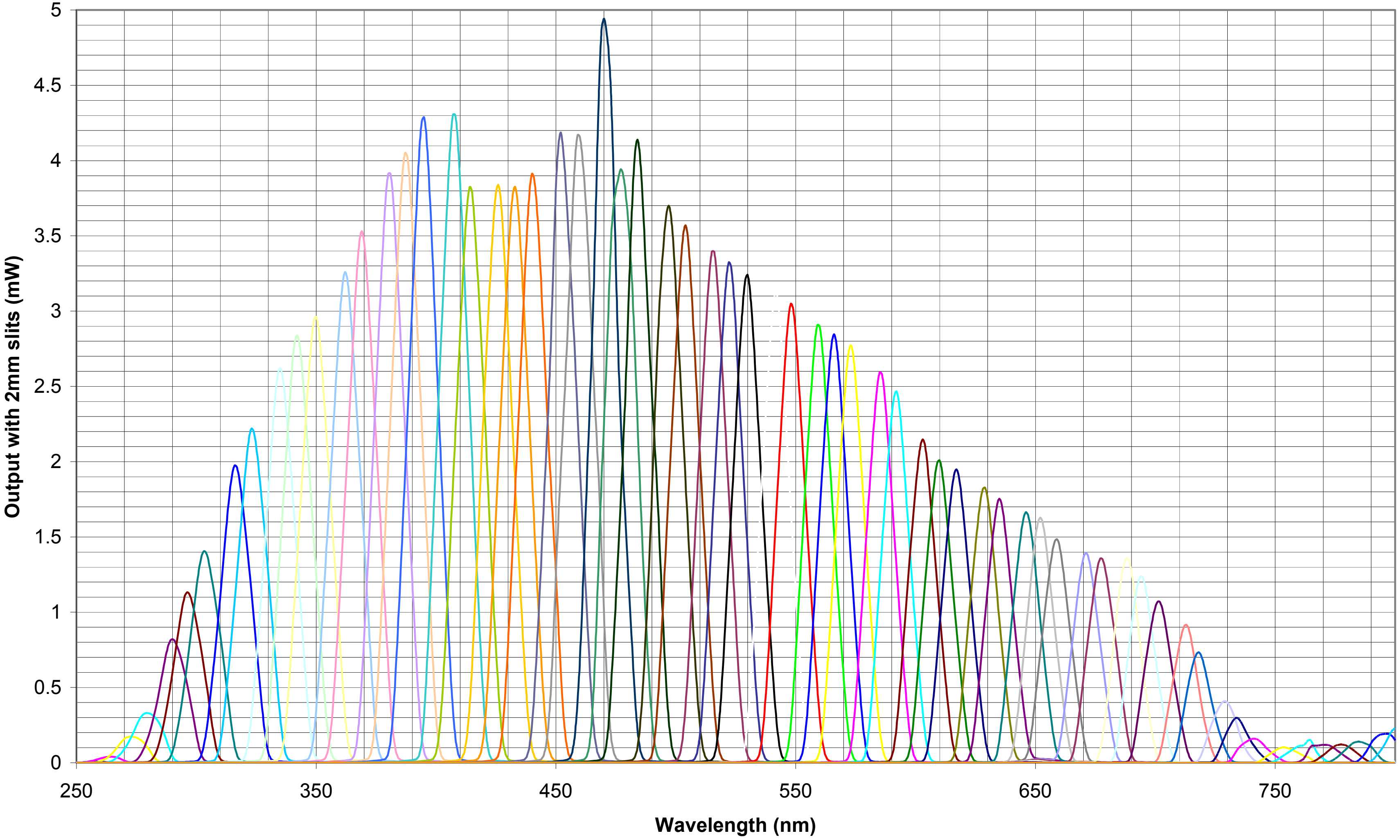


Figure 3:- Measured spectral output of SSM150Xe

8. Xenon lamp replacement

8.1 Introduction

The lamp should be changed if it has failed or if the power output of the unit has fallen to unacceptable levels.

The lamp used in the SSM150Xe is Bentham part number 19117/ Osram XBO 75W/2 OFR.

8.2 Removing the old lamp

Before removing the old lamp, read safety instructions supplied by the lamp manufacturer with the replacement lamp and ensure that you wear goggles and protective gloves. Avoid touching the lamp envelope.

It is important not to strain the lamp so follow the instructions in order.

•Switch off unit and remove power cord. If the unit has been running, wait at least 10 minutes for the lamp to cool.

•Remove the top cover by undoing the screws in the top rear corners (3mm af hex key).

The anode end of the lamp is the larger ferrule which is clamped into the brass block which has the red wire connected to it. The cathode end is the smaller ferrule which is connected to the bare flying lead by the small brass cylinder.

•FIRST Undo the anode clamping grub screw which is adjacent to the red power lead on the brass block (1.5mm af hex key).

•THEN Holding the brass cathode connector on the outer end of the lamp, withdraw the lamp from the assembly.

•Grip the silver ferrule at the cathode end of the lamp and undo the small grub screw fixing the cathode connector to the lamp (0.87mm AF hex key).

•Withdraw the old lamp from the unit and place on one side.

8.3 Inserting new lamp

As before, you must fix the lamp in the correct order to avoid straining the envelope

•Take the new lamp out of its box. Remove the plastic safety cover from the new lamp and fit it to the old lamp. Place the old lamp in the packaging for disposal.

•FIRST Holding the lamp by the cathode ferrule, attach the brass cathode connector and tighten the grub screw (0.87mm aft hex key).

•THEN Pass the anode ferrule through the hole in the ellipse and into the brass anode block.

•Insert the lamp as far as it will go and tighten the anode clamping screw (1.5mm AF hex key).

•Insert 3.7mm slits at the entrance and exit of the monochromator section.

•Replace the top cover (3mm AF hex key).

8.4 Optimising Lamp Position

•Remove the front left hand handle (3mm AF hex key).

•Remove the screw which is about half way along the upper rib on the side panel.

•Slide the central trim panel forward and remove, as seen in following image.

Figure 5:- Removing central trim panel to expose alignment screws

•Push the perspex (plexiglas) rod on the front of the optimiser unit into the output receptacle and lightly tighten the grub screw to hold it in place, as seen below.

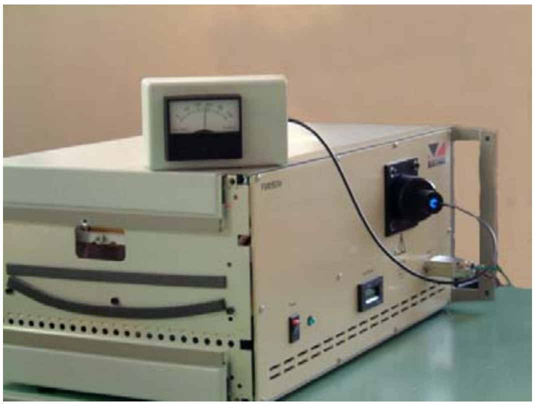


Figure 6:- Optical output measurement during alignment

•Switch on the unit and momentarily depress the time elapsed rest button on the side panel (small black peg near front). The time elapsed meter should reset to zero at this point.

•Use the software to set the wavelength to 475nm.

•Wait a few minutes for the FSM150Xe to stabilise. If the meter indicates 80 or more you can proceed to the final stage, otherwise proceed as follows.

•Refer to the figure 7 to ensure that you can identify the various adjuster screws especially the one marked "Do not adjust" which should not be adjusted.

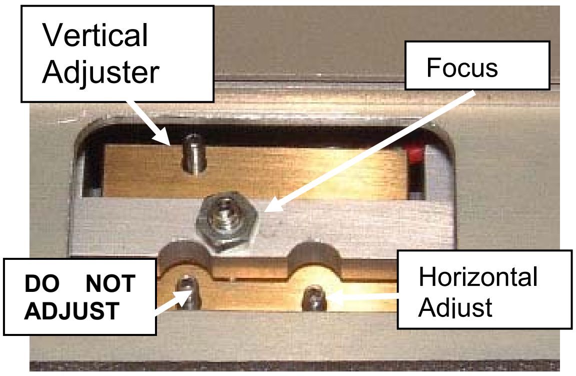


Figure 7:- Xenon lamp alignment screws

•Using a hex key (1.5mm AF), adjust the horizontal and vertical adjusting screws a little at a time until you are happy that you have maximised the output as displayed by the monitor. Access to the vertical adjust screw is via the small hole in the side panel

•If the meter now indicates 80 or more you can proceed to the final stage, step14.

•If you have maximised the horizontal and vertical positions and the meter indicates less than 80 you need to adjust the focus.

•Slacken the lock nut on the focus adjust and adjust the focus screw for maximum output (2mm AF hex key). Tighten the lock nut.

•You may want to re-optimise the horizontal and vertical settings after adjusting the focus.

•Finally replace your original monochromator slits if necessary.

9. Setting mains voltage
The SSM150Xe 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

10. System Specifications
The specifications of the SSM150Xe are as follows:-

XXX

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

•Do not touch gratings nor optics

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

•Protect eyes and skin when running Xenon lamp with cover removed during lamp replacement

•Follow carefully installation instructions of the external filter wheel

12. Monochromator Operation

12.1 Introduction

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

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

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

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

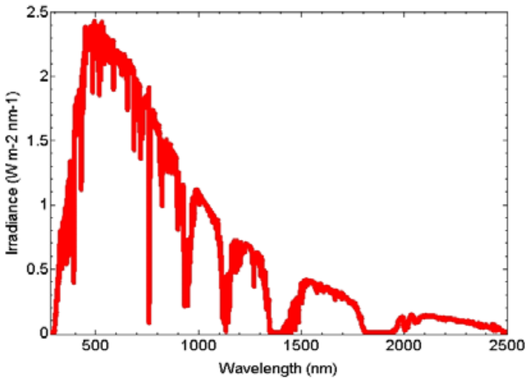


Figure 8:- Solar spectrum- from ultra violet to infrared

12.2 Light dispersion

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

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

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

12.3 Light Dispersion Mechanisms

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

Of the described techniques, only the reflection diffraction grating can be used over wide spectral range in a practical application, providing potentially very high spectral resolution. It is this technique that is employed in all Bentham monochromators.

Henceforth shall be presented the theory and operation of such a device.

12.4 Wave Interference

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

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

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

Between these two conditions varying degrees of interference result.

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

12.5 Theory of diffraction

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

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

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

This is termed single slit diffraction.

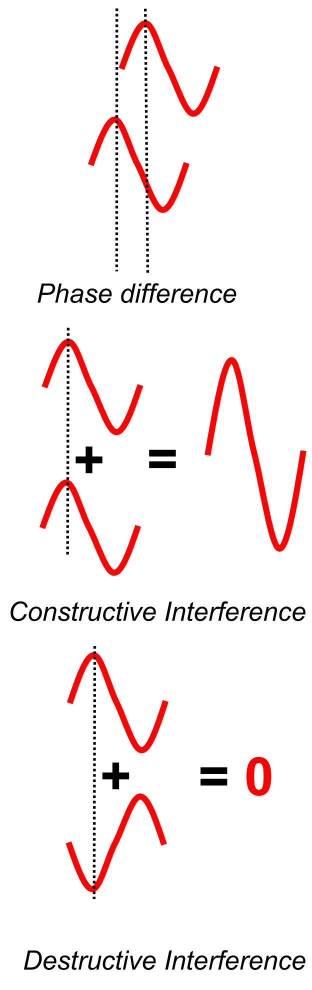


Figure 9:-Wave interference

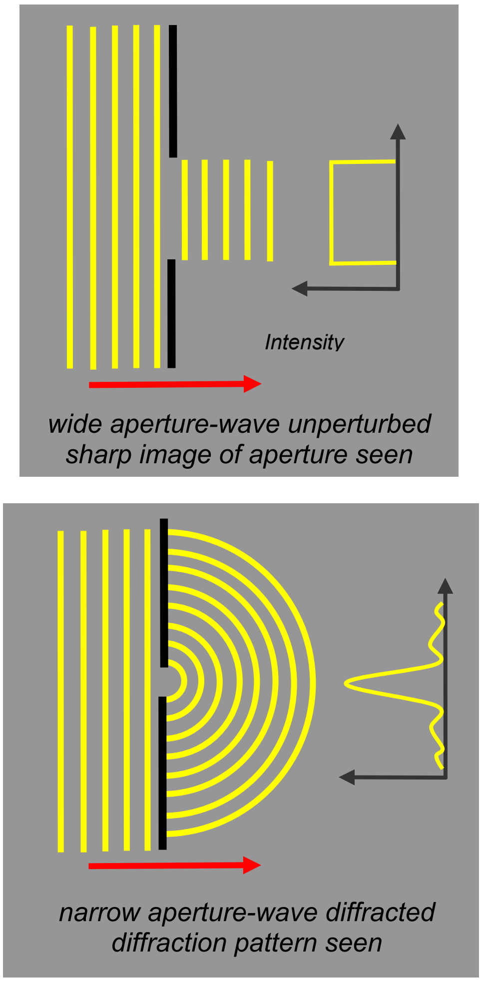


Figure 10:-Single slit diffraction

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

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

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

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

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

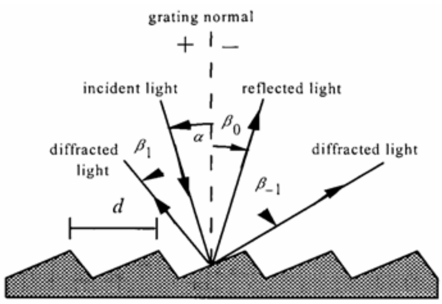


Figure 11:- Plane reflection grating diffraction

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

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

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

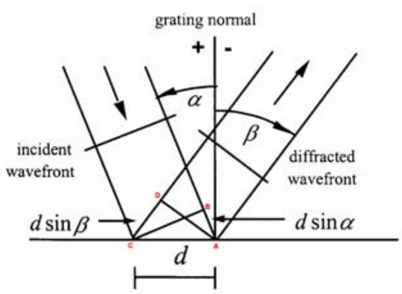


Figure 12:- Path difference between neighbouring rays

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

$$\Delta = AB + CD = d\sin\alpha + d\sin\beta \quad .....1$$

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

$$m\lambda = d(\sin\alpha + \sin\beta) \;\ldots\ldots\; 2$$

or

$$Gm\lambda = \sin\alpha + \sin\beta \;\ldots\ldots\ldots\; .3$$

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

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

Here m is the diffraction order and is an integer.

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

$$| m\lambda / d | < 2 \;\ldots\ldots\ldots\ldots\; .4$$

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

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

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

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

$$2K = a - \beta = \text{constant} \qquad 5$$

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

$$2\varphi = a + \beta \ldots\ldots\ldots\ldots\ldots\ldots 6$$

Now, substituting, the grating equation becomes:-

$$m\lambda = 2d\cos K \sin\varphi \ldots\ldots 7$$

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

12.7 Diffraction orders

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

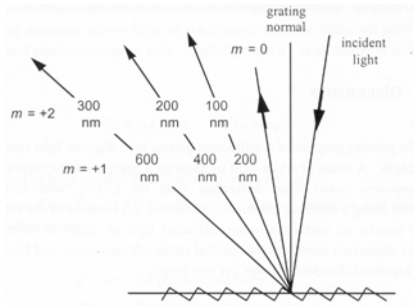


Figure 13:- Existence of diffraction orders

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

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

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

$$\lambda_1 + \Delta\lambda = \frac{m+1}{m}\lambda_1 \ldots\ldots\ldots\ldots 8$$

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

$$F_\lambda = \Delta\lambda = \frac{\lambda_1}{m} \ldots\ldots\ldots\ldots 9$$

12.8 Diffraction grating production

Gratings found in monochromators are replicas based on master gratings.

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

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

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

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

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

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

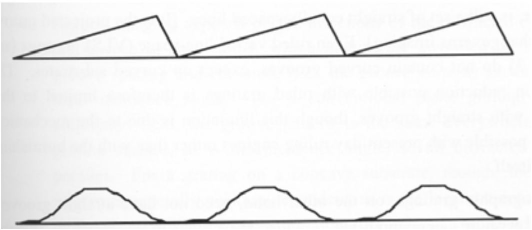


Figure 14:- Groove shape obtained using ruling (upper) and holographic techniques

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

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

12.9 Diffraction grating efficiency

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

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

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

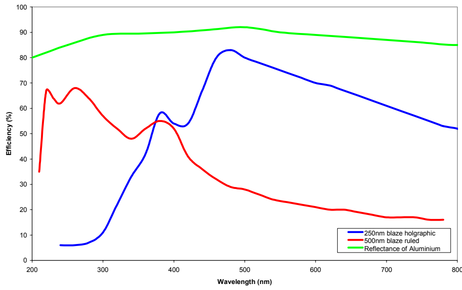


Figure 15:- Example grating efficiency curves

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

12.10 Czerny-Turner Monochromator

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

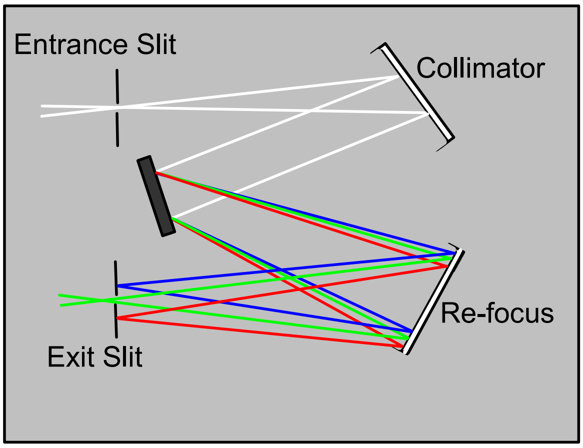


Figure 16:- Czerny-Turner configuration

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

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

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

12.11 Stepping motor drives

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

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

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

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

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

12.12 Double monochromators

When using a single monochromator such as that shown in figure 16, it is possible that light, entering from the entrance slit, be scattered off the walls and structures constituting the monochromator, reach the exit slit. Therefore, at a given wavelength, λ, an artificially high signal is measured.

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

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

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

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

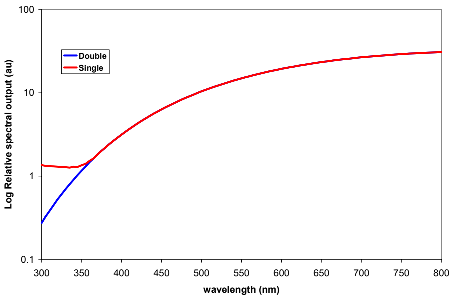


Figure 17:- Measurement of QH lamp with single and double monochromators

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

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

In the second monochromator, the desired wavelength re-selected; at the exit slit one finds that the level of the stray light has reduced to the square of the case of the single, for example a factor 10^4 down in a single, a factor 10^8 down in a double.

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

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

With subtractive dispersion, the second monochromator is operated in an inverse manner to the first in such a manner that at the exit slit there exists no net dispersion. At the exit of the first monochromator, the light to be transmitted to the second monochromator is dispersed across the slit; at the exit of the second monochromator this dispersion does not exist and all the wavelengths are combined.

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

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

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

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

Product 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:

1. Before returning the instrument, notify BENTHAM with full details of the problem; including model number and serial number of the instrument involved.

2. After receiving the above information, BENTHAM will give you shipping instructions or service 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 2 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.

BENTHAM INSTRUMENTS LTD
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NOTHING IN THIS GUARANTEE AFFECTS YOUR STATUTORY RIGHTS

WEEE statement

Bentham are fully WEEE compliant, our registration number is WEE/CB0003ZR.
Should you need to dispose of our equipment please telephone 0113 385 4352 or 4356, quoting account number 135412.