LASER SAFETY

CAUTION

Lasers are part of everyday life and most households currently have them built in to many devices such as DVDs, CDs and computers.

The most common use of lasers is in the scanners used in shops to read barcodes and price items. The laser is an essential device or tool in education and industry and many professions routinely use this technology.

We believe it is essential for students to be able to use lasers in a safe manner with the risks reduced to a minimum.

We use Class 2 lasers similar to those found in laser pointers. The strength of this laser is similar to that of the sun. Just as staring at the sun will cause damage, continuous shining of the laser into the eye will produce eye damage and blindness.

If a class 2 laser beam accidentally shines into the eye the person will blink and move the head to reduce exposure. Just like catching a ball coming out of the sun, our reflexes are fast enough to save our vision.

SAFETY RULES

- **Do not stare at the laser beam**
- **Beware of reflections**
- **View the laser beam from above**
- **Use a white card or screen to trace the path of the laser beam**

On-off

AAA

Slide and holder
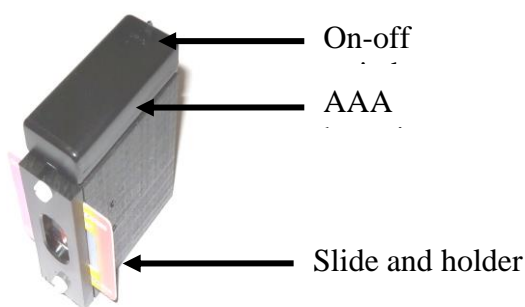
Dual Laser Unit	Supplied
Diffraction Grating	Supplied
Single Slits	Supplied
Double Slits	Supplied
Blank Slide	Supplied
Calculator	Not Supplied
Tape Measure	Not Supplied

The dual laser unit is operated by a switch on the battery holder. The compartment slides open for two AAA batteries to be inserted. The slide is clamped in place on the front of the unit and a piece of tape can be used to block one of the laser beams if necessary. The base magnets allow the unit to be securely attached to a (magnetic) surface.

DIFFRACTION BY SLITS, DUST AND APERTURES

Objectives

To demonstrate the wavelength dependence of diffraction
To show the importance of diffraction in optical communication
To use lasers safely
Calculate laser wavelengths

## Equipment

	Dual Laser Module		Diffraction Grating
	Tape Measure (not supplied)		Calculator (not supplied)

Introduction

Each optical fibre in the National Broadband Network can carry up to 100 different channels of data using infra-red lasers in the communication bands between 1460 and 1625nm.

Each laser can be tuned so that the difference between adjacent lasers is less than 1nm. This technique gives rise to Dense Wavelength Division Multiplexing or DWDM as many lasers are coupled into the same fibre.
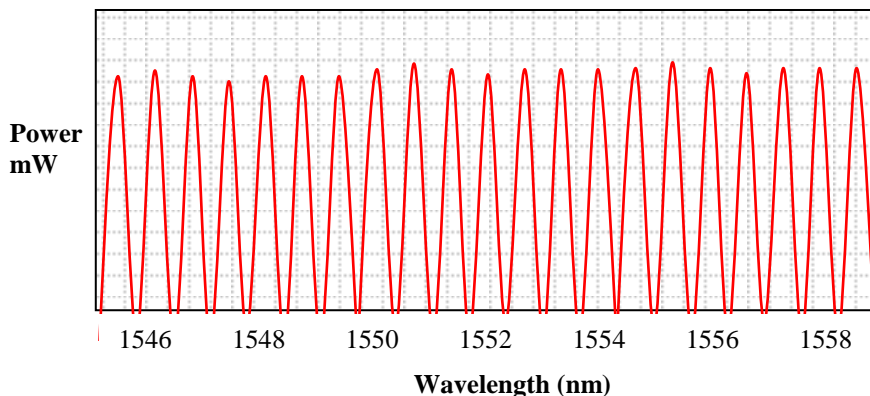
DWDM: 21 laser channels with a 0.8nm spacing

Each laser signal passes through the fibre and doesn't interfere with the adjacent channels. To extract a channel a Fibre Bragg Grating (FBG) is used to reflect a particular wavelength. The FBG is a regular variation in the refractive index of a short length of the fibre and is written into the fibre using a short wavelength Ultra-Violet laser.

The spacing of the refractive index variations can be matched to a laser wavelength and so this particular laser will be reflected. A circulator is used to feed the reflected channel to the next stage of processing.
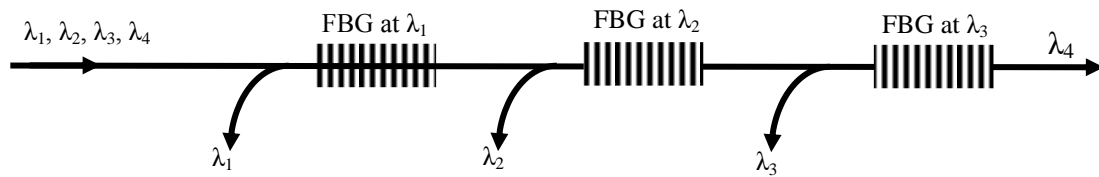

Fibre Bragg Gratings spaced along a length of optical fibre to extract four different wavelengths ($\lambda_1 - \lambda_4$)

The dual laser unit has a red laser (650nm) and a green laser (532nm)

The lasers are shone through a transmission diffraction grating to observe the phenomenon. The amount of bending depends on the wavelength of the light and the spacing of the lines on the diffraction grating. The light can constructively or destructively interfere to leave light and dark areas.
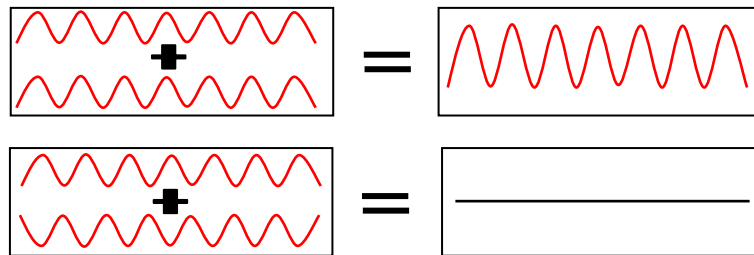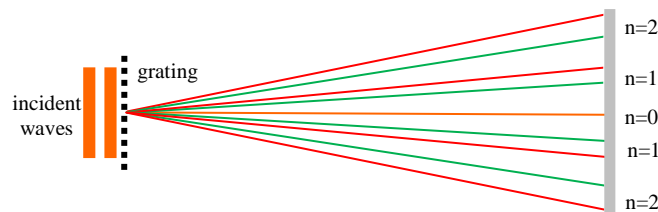

Constructive and destructive interference of light waves
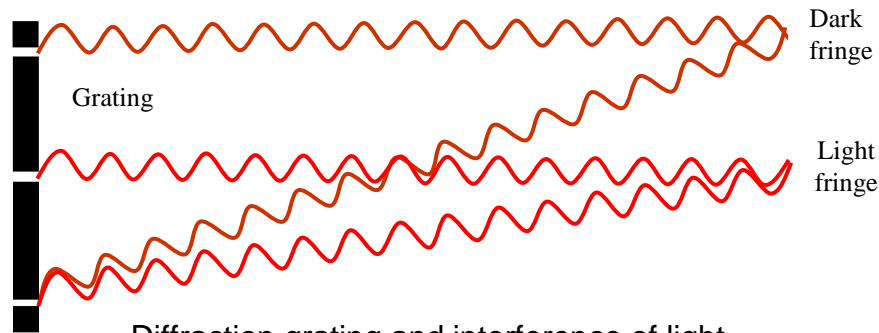

Diffraction grating and interference of light

The diffraction grating produces several sets of diffracted spots or orders. The n=1 spots can be seen clearly and possibly n=2. Initially calculate wavelengths using n=1 for the spot closest to the un-deflected beam.

Diffraction orders for lasers of two different wavelengths

3

Activity

The dual laser unit is operated by a switch on the battery holder. The compartment slides open for two AAA batteries to be inserted. The diffraction slide is clamped in place on the front of the unit and a piece of tape can be used to block one of the laser beams if necessary.
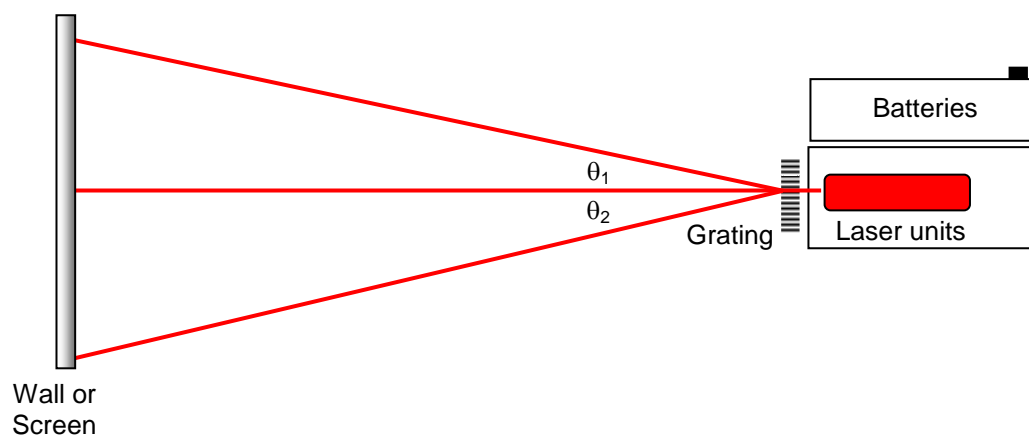

Experimental arrangement

The wavelength λ of the light can be calculated using **nλ = d Sin θ**

Where λ is laser wavelength, d is the spacing between adjacent lines on the diffraction grating and n is the order of the spots, with the brightest set of spots being n=1.

Check the number of lines per millimetre on the grating (500lines/mm) and work out the distance between the lines using 1/500. Note there is also a 1000lines/mm diffraction grating.

The grating lets some light straight through and using this point and the diffracted dot on the screen θ can be calculated using a right angled triangle.
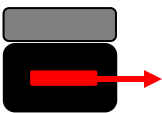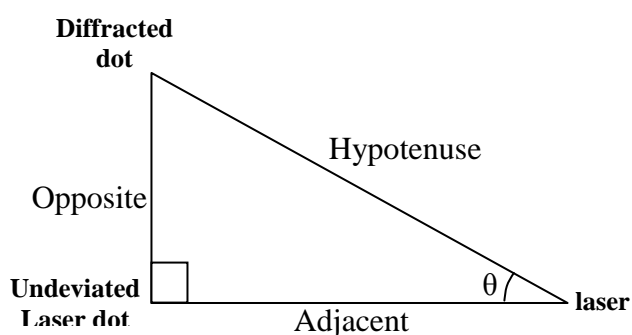

$$\sin \theta = \frac{opp}{hyp}$$
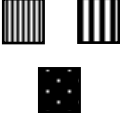
Calculate θ_1 and θ_2 and then take the average

Calculate λ and convert your answer to nanometres the usual units for light wavelength. 1nm = 10^{-9} metres or 10^{-6} mm

# DIFFRACTION BY SLITS, DUST AND APERTURES

minilabs

Objectives

To observe diffraction patterns from slits, lines, dust and apertures
To use lasers safely
Calculate slit and line widths
See an example of how diffraction is used to make chocolate

Equipment

	Dual Laser Module		Single slits, double slits, open slide
	Tape Measure (not supplied)		Calculator (not supplied)

Introduction

When light passes an edge it spreads out causing diffraction. This effect is particularly important in the design of optical instruments. The shape of an aperture or object determines the shape of the diffraction pattern. For example a circular aperture will produce a diffuse circular pattern known as Airy's disc and a slit will produce a series of fringes.
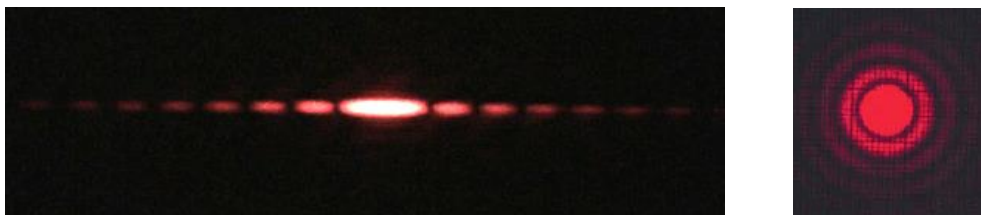

Diffraction patterns formed by a laser shining through a slit and pinhole

When you look at a distant street lamp there may be a corona surrounding it. This is actually a diffraction pattern determined by the aperture of your eye. Occasionally the moon exhibits a corona due to diffraction from the small water droplets or ice crystals in the air above us.

The size of a circular aperture (d) can be calculated using:

$$Sin\,\theta = \frac{m\lambda}{d}$$

Where m = 1.22, λ = laser wavelength and $\sin\theta = \frac{opp}{hyp}$
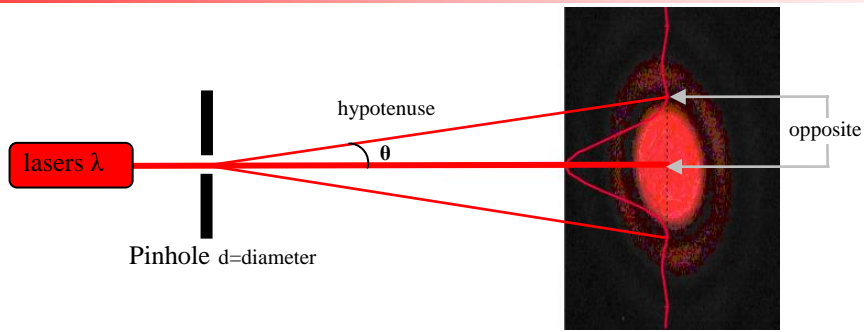
Diffraction and light intensity through a pinhole

In general terms the smaller an aperture is then the greater the effect of diffraction and interference. This knowledge is useful because many optical instruments have small circular apertures.

Usually for an optical instrument it is desirable to limit the diffraction. This means the central spot for circular apertures must be as small as possible. By inspection of the equation above we can see that we need to make d as large as possible. Microscope objective lenses provide an example, with the better lenses having the larger apertures.

The size of a slit (d) can be calculated using the first minima and:
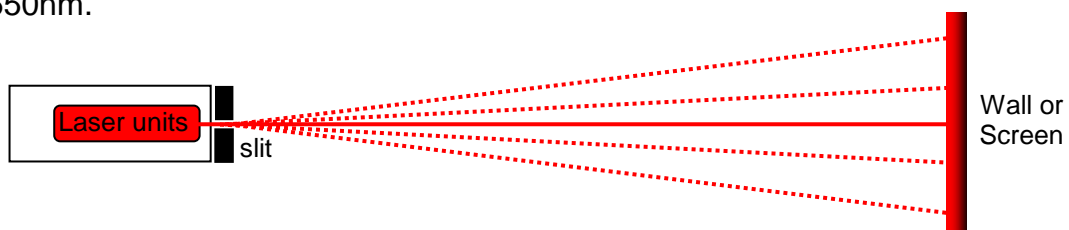
$$Sin\,\theta = \frac{m\lambda}{d}$$

Where m = 1, λ = laser wavelength and $\sin\theta = \frac{opp}{hyp}$
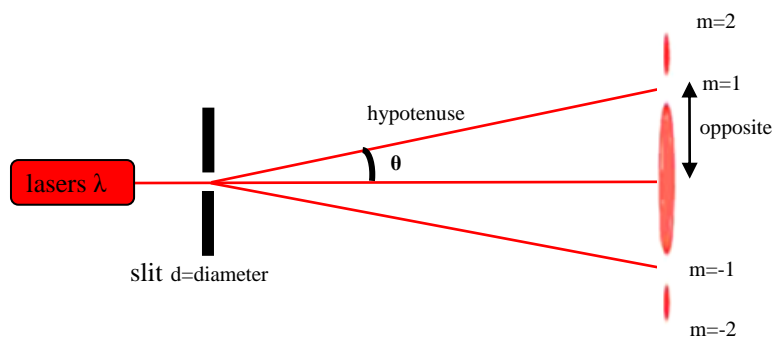
Diffraction through a single slit

Activity: Single Slit

Calculate the width of the slits in the single slit slide based on the diagram shown above. Remember the two lasers have wavelengths of 532nm and 650nm.


Observing single slit diffraction

Activity: Single Lines and a Hair

Replace the single slit slide with the open slide containing a hair taped to the edges. What are the similarities and differences between the diffraction patterns for a slit and hair? Do you think they are equivalent to each other?

The diameter of the line or a hair (d) can then be calculated using the first minima or dark band and:

$$Sin\theta = \frac{m\lambda}{d}$$

Where m = 1, λ = laser wavelength and $\sin\theta = \frac{opp}{hyp}$
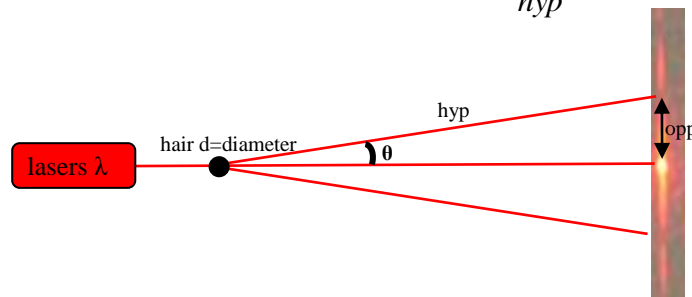
Observed pattern for diffraction by a hair or line

Measure the distance from the central bright spot to the first dark band and then the length from the hair to the screen. Use these values to calculate the width of the hair (d)

Activity: Cocoa and chocolate

To make chocolate it is necessary to grind up the cocoa beans to a particle size of around 20 microns. Particle size is extremely important in making high quality chocolate.

Chocolate and a diffuse diffraction pattern of fine particles

One of the easiest ways to monitor the particle size is to use a laser and monitor the diffraction pattern. To observe a diffraction pattern any fine dust can be used. If Lycopodium powder is available this will give a good diffraction pattern. The powder can be placed on a microscope slide and the slide positioned so the lasers pass through the dust. Choose a suitable distance to the wall to give a circular diffuse pattern as shown above.

1. Measure the distance from the slide to the wall (L)

2. Measure the diameter of the central bright spot and divide by 2 to get the radius (R)

3. Note the wavelength of the laser used (λ)

$$d = \frac{1.22\lambda L}{R}$$

The diameter of the particles (d) can be calculated using the above equation. Lycopodium spores are typically less than 50 microns in diameter.

Activity: Pinholes

Make pinholes using a piece of aluminium foil in a slide holder. The pinholes need to match the position of the laser.

Calculate the diameter of the pinholes using the equations described earlier.

Extra Activity

Look at the diffraction patterns formed by the double slits and provide explanations for your observations

Appendix: slit and line dimensions

Single Slit opening mm	0.03	0.05	0.08	0.10	0.12	0.14
Double Slit spacing mm	0.05	0.08	0.10	0.12	0.15	0.17