R04839 LED.laser **NFU 737M**

Purpose:

The LED.laser is a class 2 light source, emitting red light at 640nm and has a power output of 1mW. The unit can be used to investigate reflection, refraction, diffraction, interference as well as in measuring the speed of light.

Safety advice:

This advice is not a replacement for a formal risk assessment, which should be carried out according to your school or LEA policy. CLEAPSS Laboratory Handbook 12.19. should be read before use.

Common safety precautions;

• Do not use with any collimating instrument such as a microscope or telescope.
• Impress on students the danger of direct viewing or of direct reflections from glass or polished surfaces so that, in the event of accidental exposure, they will react by closing the eyes and turning the head.
• Students should be no closer than 1m from a laser experiment.
• Display warning notices when lasers are in use.
• Never operate the laser with the top cover removed.

A full risk assessment is needed for this apparatus. The main danger presented is from the effects of flashing lights, which can trigger seizures in sufferers of **photosensitive epilepsy**.

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This applies only when the LED.modulator or LED.strobe is used to drive the LED.laser between 3 and 30Hz (typically). Some people are affected by flash rates up to 60Hz. Higher rates are unlikely to cause problems.

Prolonged exposure to a strobe can cause discomfort and disorientation, so exposure time should be minimised. If possible, provide some ambient light during experiments, only removing it for short durations to maximise the effect of the strobe.

There is a reset button on the LED. strobe unit which will instantly set the frequency to 0Hz in case of emergency.

Disposal of Waste Electrical and Electronic Equipment (WEEE)

Do not dispose of this product with household waste

- For the proper treatment, recovery and recycling please take this product to an appropriate collection point.
- If you are unsure where this is, contact your Local Authority
- By disposing of this product correctly you will be providing positive help to the environment.

Basic operation:

A plug top power supply is included with the LED.laser. It has a flat bottomed cylindrical housing that allows for bench working and stability. There is also a housing on the back of the unit so that it can be mounted on a retort rod (if required).

Activities:

Experiment 1 – Reflection, refraction, diffraction and interference

Experiment 2 – Flickering lights

Experiment 3 – Sound from light!

Experiment 4 – Speed of Light, it's constant surely?

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Experiment 1 – Reflection, refraction, diffraction and interference

Reflection;

Set up the LED.laser, a plane mirror and a screen and investigate how the light can be reflected. Care should be taken to ensure no persons are in the path of the reflected beam. Repeat the experiment using a right angled prism and see how the reflected image changes. The image reflected by the mirror should be of a poorer quality due to dispersion effects on the beam caused by multiple reflections from the surface of the glass and the reflective backing, See Fig. 1 below. In the prism, total internal reflection takes place purely at the boundary between the glass and the air leading to little or no beam dispersion.

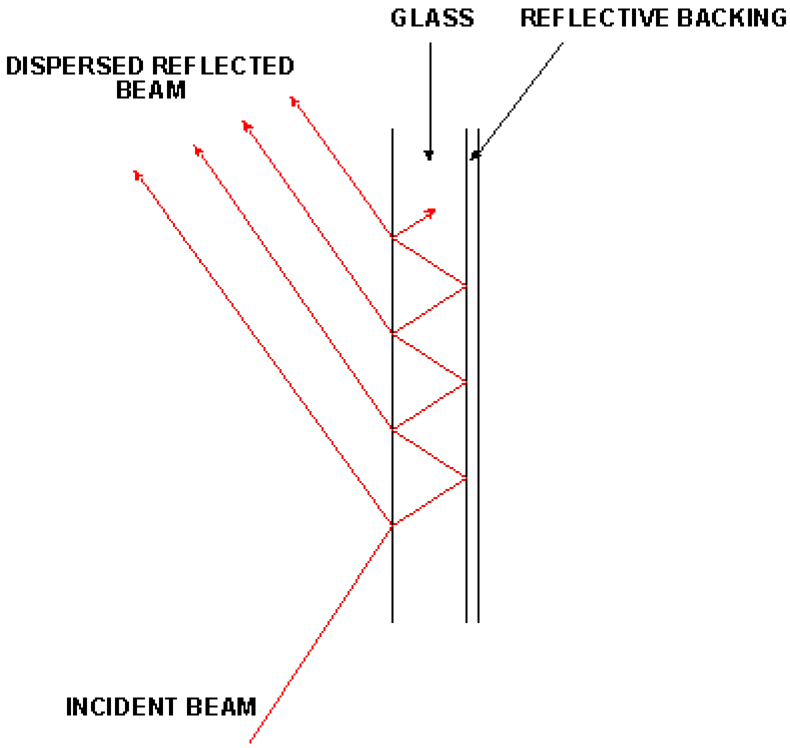

Figure 1: Beam dispersion in a mirror.

Refraction;

Fill the tank with water and add a few drops of milk to make the laser visible. Aim the LED.laser through the tank at different angles and note how the beam is refracted at the boundaries. Notice how altering the angle of incidence around the critical angle causes the method of propagation to alter from refraction to total internal reflection. By setting up a refracted path and measuring the incident and refracted angles it is possible to calculate an approximation of the refractive index of water, see Fig. 2 below. The measurements can be tricky to take and so will not yield an accurate result.

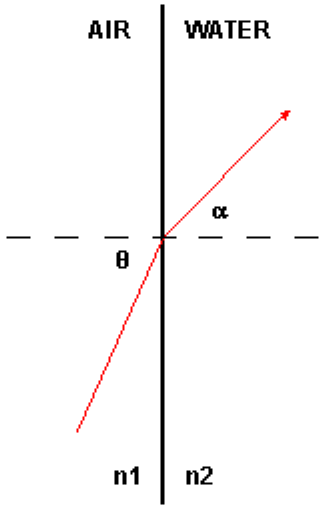

Figure 2: Refraction of laser in water

Measure the incident and refracted angles θ and α, the refractive index of water (n2) can then be determined using:

$$n1\sin\theta = n2\sin\alpha$$

where n1 is the refractive index of air

Diffraction;

Using a diffraction grating produces a highly accurate determination of wavelength. If measurements are taken carefully, a value of wavelength to within 1% of the true value is possible.

This experiment needs to be performed in an area of low ambient light. A total blackout is not necessary. Set up the LED.laser on a bench and focus the beam perpendicularly on the screen at a distance of approximately 2m. Position the diffraction grating at right angles to the beam in the path of the beam so the laser falls in the centre of the grating, See fig. 3 below.

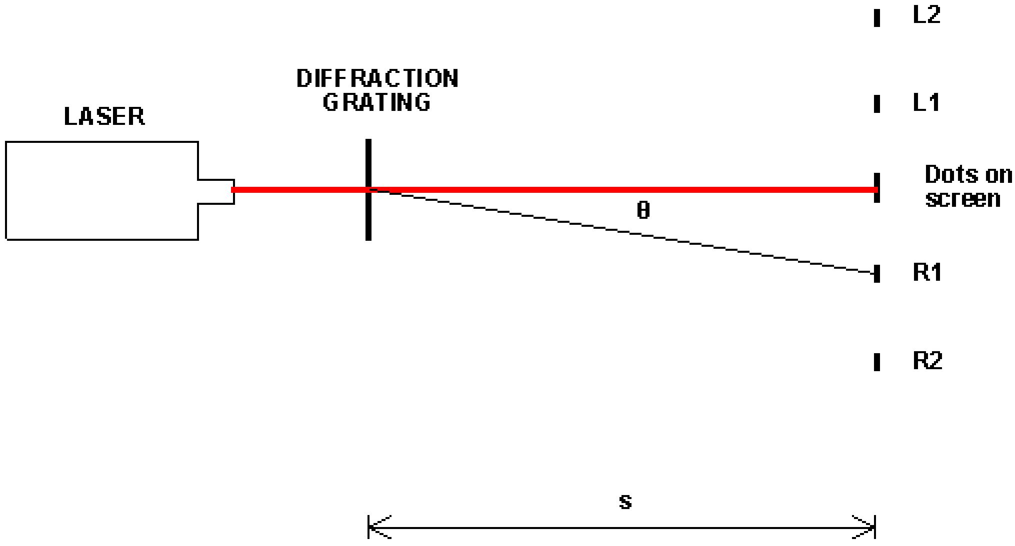

Figure 3: Diffraction grating set up

There should now be at least 7 dots visible on the screen symmetrical about a bright centre dot. The intensity of the dots will diminish the further they are from the central bright spot. Additional focusing lenses should not be necessary due to the small angular dispersion of the laser beam. The dots will probably be brighter on one side than the other due to the way the diffraction grating has been manufactured.

On the screen, measure the distance between corresponding dots i.e. L1 and R1 on the diagram above. Also measure the distance between the grating and the screen (s on the diagram above). If the diffraction grating is not labelled with the line spacing it will be necessary to measure the line separation using a microscope. Be careful to convert any stated line spacing given in lines/mm to a line separation in metres.

Typical Result and Calculation

For constructive interference to take place at the screen:

$$d\sin\theta = n\lambda$$

where

d = the line spacing of the diffraction grating in metres

θ = angle from central position to area of constructive interference

n = an integer

λ = the wavelength of the light in metres

Tanθ = L1R1/2S

Using this, θ and therefore sinθ can be found. Hence the wavelength can be determined from

$$\lambda = d\sin\theta/n$$

By altering the experimental set up and taking and recording a number of measurements for the values of L1 to R1, θ and s, it will be possible to arrive at an accurate value for the wavelength of the laser. Use of different diffraction gratings (if available) will also allow the experiment to be repeated to arrive at the same result.

Interference;

This experiment demonstrates the effects caused by division of the wavefront which occurs when interference takes place between light from two coherent sources. The two coherent sources are derived using a LED.laser and a double slit. Each slit acts as a source of circular waves. The two circular wavefronts then travel to the screen and if they arrive in phase they reinforce to create a fringe. If they arrive out of phase they cancel out. This experiment can be performed using a LED.white but better results are obtained using a LED.laser.

This experiment should be performed in dull light. A full blackout is not necessary but darker conditions will make the fringes easier to see and more fringes will be visible. Set up the laser on a bench and focus the beam on the screen a few metres away. Place the double slit approximately 100mm from the laser, ensuring the beam falls squarely on both slits. You will now see on the screen a central bright band which is the original path of the laser beam. This will be bordered on both sides by regular bright bands which become dimmer away from the central position, see fig.4 below. If the distance from the double slit to the screen is approximately 1m then bright fringes quite close together will be seen. If the slit-screen distance is as great as 5m then a good blackout will be required to adequately view the fringes.

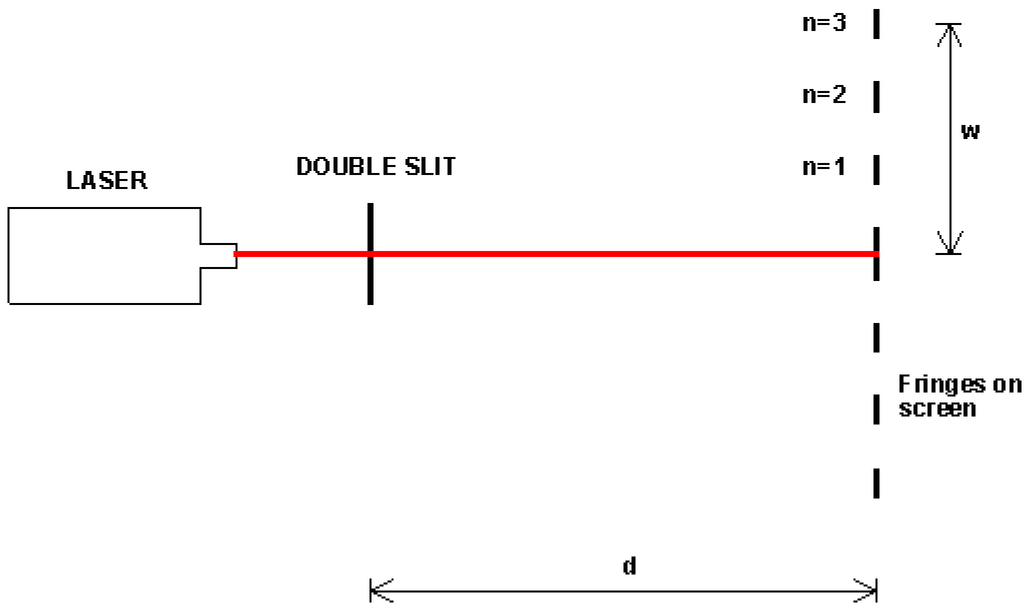

Figure 4: Young's 2 slit experiment

Pick a fringe and measure the distance on the screen between this fringe and the central band. Note the measurement and also the order of the fringe (i.e. 1st order, 2nd order etc). Measure and record the distance between the double slit and the screen. Measure and record the distance between the two slits. This can be done using a travelling microscope or with an optical projection method.

The wavelength of light can then be calculated using the following formula:

$$n\lambda = (sw)/d$$

where: n = order of fringe (an integer)

l = wavelength of light in metres

s = Slit separation in metres

w = distance to the nth band from the central band in metres

d = distance from the double slit to the screen in metres

Typical Result and Calculation

Fringe order 1

Slit - screen distance 1.5m

Slit separation 0.047mm

Distance from centre to 1st fringe 20cm

Wavelength of light = sw/dn

= (0.000047) x (0.02) / (1.5) x 1

= 626.7nm

Experiment 2 – Flickering lights

Use the plug-top supply provided with the LED.laser of your choice to power the LED.modulator and then plug the captive output lead of the LED.modulator into the power socket of your LED.laser.

Connect an LED.Rx to an oscilloscope via the rear BNC output plug and an appropriate BNC to BNC plug connector.

Select the appropriate light source with the "Device Select" button, and select the 1MHz int. the light source is now flickering at 1 million times a second.

Ensure that the main focus of the light is lined up with the LED.Rx sensor, this will facilitate optimal signal transmission.

The trace being displayed on the oscilloscope will show the on / off cycle with which the light source is operating on. Check that you see a series of pulses of frequency 1MHz. The transmitter is crystal controlled and the pulses are 1µs apart. You can use this to check the accuracy of your oscilloscope, but this will not necessarily apply to all timebase ranges. Increase the timebase speed to 0.1µs/d iv or larger (use the x10 control). Adjust the controls so that you can see an enlarged pulse to the left hand side of the screen.

Experiment 3 – Sound from light!

Use the plug-top supply provided with the LED.laser of your choice to power the LED.modulator and then plug the captive output lead of the LED.modulator into the power socket of your chosen LED.laser.

Connect a LED.Rx to an amplifier via the rear BNC output plug and an appropriate BNC to 4mm plug connector. Connect a suitable sound generator (mp3/cd player/stereo/DAB radio) via a 3.5mm to 3.5mm cable to the 3.5mm audio jack on the back of the LED.modulator.
(If you are using a dual trace oscilloscope you are able to connect the LED.modulator via the BNC plug to one of the oscilloscope's channels in, this will give you a visualisation of the audio signal being transmitted by the LED.modulator via the LED.laser and to the LED.Rx.

On the LED.modulator control panel, select the appropriate Ext. Input (3.5mm) and commence playing of the sound via your audio device. Ensure that the main focus of the laser light is lined up with the LED.Rx sensor, this will facilitate optimal signal transmission.

Experiment 4 – Speed of Light, it's constant surely?

Any double-beam oscilloscope can be used which has a timebase capable of speeds up to 0.1µs/div, although 0.05µs/div would be better if the experiment is to be conducted over shorter distances.

Running the experiment for the first time is best done in subdued lighting. With practice, the apparatus can be used in a room that is normally illuminated. It is helpful to have assistance while setting up.

Stage 1: Light transmission over a large distance

Using 2 retort stands, mount the LED.laser and LED.Rx ~1m apart (this is a rough guide, and will ultimately depend upon how you reflect the light beam back). Use the plug-top supply provided with the LED.laser to power the LED.modulator and then plug the captive output lead of the LED.modulator into the power socket of your LED.laser.

Position a mirror on a secure mount at least 10m away, this will give you a journey distance of 20m. Now adjust the position of the LED.laser and LED.Rx so that the light beam is transmitted on to the mirror and reflected back on to the LED.Rx phototransistor. It is useful to use a lens/magnifying glass to focus the beam of light on to the LED.Rx phototransistor for better signal resolution.

Connect both the LED.modulator & LED.Rx to the oscilloscope via the appropriate BNC output plugs and an appropriate BNC to BNC plug connectors. Suggested set up would be connecting the LED.modulator to CH1(Y1) trace of the oscilloscope, with the LED.Rx being connected to CH2(Y2) trace of the oscilloscope.

Turn the CH1 sensitivity to 0.5V/div and the timebase to 1µs/div. Set the trigger source to CH1. Check that you see a series of pulses of frequency 1MHz. The transmitter is crystal controlled and the pulses are 1µs apart. You can use this to check the accuracy of your oscilloscope, but this will not necessarily apply to all timebase ranges. Increase the timebase speed to 0.1µs/d iv or larger (use the x10 control). Adjust the controls so that you can see an enlarged pulse to the left hand side of the screen. Set the sensitivity of CH2 to 1V/div.

Set both CH1 and CH2 so that their inputs are a.c. coupled. Adjust the Y position of both channels so that they have the same zero. Move the position of the LED.Rx so that the pulses have the same height. Measure the delay and keep this for future reference, as it is unlikely to change for a given set of equipment. Remember from which point on the transmit pulse the delay was measured.

The received pulse is somewhat behind the transmitted pulse, because of delays in the transmitter, in the light path, and the receiver. Both the transmitter and receiver cause some distortion of the pulse, so the received pulse is longer and rounder than the transmitted pulse. Measure the light path from the transmitter to the receiver. On trace CH2, you should be able to see the received signal. Increasing the CH2 sensitivity may help. The receiver adjustment is relatively critical; the transmitter adjustment is not. Expect a signal of 100mV or more with a path length of 20 metres.

Stage 2: Light transmission over a short distance

Using 2 retort stands, mount the LED.laser and LED.Rx so that they are facing each other and set up 10cm apart.

Adjust the CH2 gain so that the received pulse is once again the same height as the transmitted pulse. Measure, on the oscilloscope screen, the distance between the original received signal and note the difference in signal distance compared to distance for stage 1 setup.

Stage 3: The (constant) speed of light, c?

Measure the distance light is transmitted in stage 1. Subtract from it the distance of transmission in stage 2. Calculate the speed of light by dividing the increase in light path by the extra time delay. Typically for a 15m distance, time will be delayed by 0.05µs. Does this ring true for the values that have been measured?