Laser Pointer Education Kit

#45-211

INDUSTRIAL FIBER OPTICS

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Revision - A

Printed in the United States of America

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Introduction

This manual contains suggestions for activities, demonstrations, experiments, and laboratory investigations that can be performed using any laser pointer or source and Industrial Fiber Optics' Education Kit #45-211. This education kit contains selected optic components to help perform most of the activities and experiments described in this manual.

Industrial Fiber Optics makes every effort to incorporate state-of-the-art technology, highest quality, and dependability in its products. We constantly explore new ideas and products to best serve the rapidly expanding needs of industry and education. We encourage comments that you may have about our products, and we welcome the opportunity to discuss new ideas that may better serve your needs. For more information about our company and products refer to ***http//www.i-fiberoptics.com*** *on the Worldwide Web.*

Thank you for selecting this Industrial Fiber Optics product. We hope it meets your expectations and provides many hours of productive activity.

Sincerely,

The Staff at Industrial Fiber Optics

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Kit Components

Qty.	Name	Description
1	Holographic Diffraction Grating	Holographic diffraction grating has 750 lines/mm. It is used to measure the wavelength of the laser beam.
2	Polarized filters	Transmits light waves that vibrate in one plane and attenuates the intensity of light waves vibrating in other planes.
2	Front Surface Mirrors	Changes direction of incident laser beam. It is used for light shows and experiments involving laws of reflection.
1	Lens, Long Focal Length	Converges laser beam to a sharp focus.
1	Lens, Short Focal Length	Initially converges, and then diverges laser beam. It is used together with the long focal length lens to collimate the laser beam. This minimizes the beam divergence over long distances.
1	Black Vinyl Cap	Used to mount lenses to the front of the laser pointer.
1	Cylindrical Lens	The purpose of this lens is to change the shape of the beam spot to a straight line.
1	Solar Cell	The solar cell generates a small voltage that is proportional to the intensity of light that illuminates the dark side of the cell.
1	Rectangular Prism	Used for splitting the laser beam into two parts. It is also used for index of refraction experiments.
1	Fitted Case	Plastic case with hinged cover.
1	Color Filter Set	Contains three color filters for color transmission and absorption experiments (red, blue, and green filters).
1	Manual	Laser Pointer Education Kit #45-211

SAFETY NOTES

Unlike high-power industrial lasers, low-power laser pointers are incapable of burning, cutting, or welding. However, because the beam is so intense and concentrated it should always be treated with common sense and caution.

The beam does not contain any invisible, exotic, or harmful radiations. Never the less, long-term exposure to any bright light can injure the delicate tissues of your eyes. Just as you should never deliberately stare directly into the sun or the bright beam coming from a classroom projector for a prolonged time, you should *never deliberately stare directly into the concentrated beam coming from your laser pointer*. See the back cover for general safety practices.

Table 1. Common abbreviations used in this manual.

Abbr.	Long version	Numerical representation
mW	milliwatts	1 x 10-3 watts
µW	microwatts	1 x 10-6 watts
nW	nanowatts	1 x 10-9 watts
mm	millimeters	1 x 10-3 meters
µm	micrometers	1 x 10-6 meters
nm	nanometers	1 x 10-9 meters

UNPACKING AND PREPARATION FOR USE

As soon as you unpack this kit, it is important that all items are checked in accordance with the instructions given here. Spending a few minutes now can avoid many problems and greatly extend the useful lifetime of the kit.

1. Check that none of the items are missing from your kit. Refer to the kit component list on page *iv*.

2. The diffraction grating in the kit is a holograph. Be careful not to rub or scratch its surface. Clear acetate sheets or glass plates can protect the holograph from damage. These protective coverings can be removed when precise measurements are required.

3. A thin semi-transparent film protects both sides of the Polarized filters. Carefully peel off and discard the protective films. If desired, the Polarized filter can be protected from scratches and fingerprints by covering it with transparent acetate or glass plates. Tape the edges to hold the assembly together.

4. The reflective surfaces of the two front-surface mirrors are protected with a thin, blue film covering. Very carefully peel off and discard the protective films, when precise measurements are required. Careful handling is necessary to avoid damaging the mirrors with dirt and fingerprints after the protective films have been removed.

5. The cylindrical lens is cemented to a vinyl cap that fits over the front of your laser pointer. Be very careful when mounting or removing this cap. Excessive stresses can break the cement bond.

6. An extra vinyl cap is provided for mounting a lens over the front of your laser pointer. First, place the lens inside the cap. Then press the cap over the front end of the laser pointer.

UNPACKING AND PREPARATION FOR USE (CON'T)

7. Two terminals are provided on the back of the solar cell. Solder a length of wire to each of the terminals. Connect the other ends of these two wires to a plug that fits into the microphone jack of your audio amplifier. For further details, see page 9.

8. Preserve the fitted case that comes with this kit. After each use, check that every part is returned to its proper place.

APPLICATIONS AND DEMONSTRATIONS

Here are a few suggestions for using your laser pointer for everyday applications in many environments including the classroom and office.

Pointing at a Projected Image on a Screen

One of the most obvious uses for a laser pointer is to call attention to a portion of a projected image during a presentation, lecture, or slide show. The small red spot cast by the laser beam can also be used to highlight a feature on a movie screen, television screen, or even a computer monitor. For instruction, it is much more effective than having observers try to follow the movements of a cursor on the computer display screen.

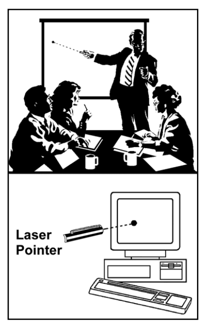

Figure 1.

Pointing at Objects Indoors and Outdoors

Use the laser pointer to call attention to details on charts, artwork, displays and special features in the classroom, museum, and art gallery. At night, use it outdoors to spot owls and communicate with prearranged signals. Do not point directly at animal's eyes or face.

APPLICATIONS AND DEMONSTRATIONS

Making the Laser Beam Visible

A laser beam is invisible unless there are objects in its path that reflect or scatter the light toward your eyes. In a dark room, turn the laser pointer on and shake some chalk dust along the beam path. Each speck of chalk dust becomes a reflector so the laser beam can be seen and photographed.

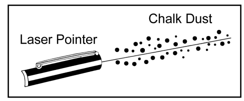

Figure 2.

⚠ **Caution:** Avoid using chalk dust in the vicinity of computers or other sensitive electronic equipment.

Viewing Imperfections in an Ice Cube

In a darkened room, direct the laser beam through an ice cube. The light is scattered when the beam encounters imperfections in the crystalline structure of the ice.

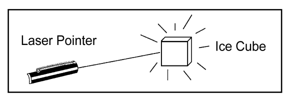

Figure 3.

Using Color Filters to Absorb Laser Light

Shine the laser beam through the color filters included in the education kit. Observe how the color of the filter affects the laser beam. Try experimenting with colored cellophane, colored plastics, and colored liquids. Notice how easily the laser beam travels through a jar of cranberry juice but how it can be completely absorbed by some bottles containing clear ginger ale.

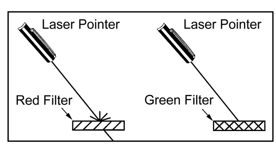

Figure 4.

APPLICATIONS AND DEMONSTRATIONS

Scanning Bar Codes

Bar code data on grocery products can be decoded because the bar code reflects laser light in a distinctive pattern from the contrasting bars and spaces. The reflected light is received by a photodetector and the signals are converted into digital data that can be processed by a computer. Move the beam of the laser pointer across the black and white bars in Figure 5. Notice the differences in the reflected light when different bars are selected.

Figure 5.

Reflection and Refraction at Water's Surface

Fill a florence flask halfway with water and add a small amount of milk powder it to make the water slightly cloudy. Then fill the top half of the flask with smoke. Aim the laser pointer's beam through the bottom of the flask. Observe the changes in the beam's intensity as the angle between the laser beam and the water's surface is decreased.

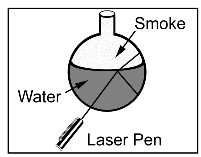

Figure 6.

Observing Internal Reflections in a Test Tube

Fill a test tube with water and add a small amount of milk powder to make the water slightly cloudy. In a darkened room, aim the laser beam so it enters the bottom of the test tube and exits at the top. Then, slowly change the angle of the test tube. Notice that instead of exiting out the side of the test tube the beam reflects in a zigzag pattern until it emerges from the top of the water. This illustrates the internal reflections that take place in a fiber optics cable.

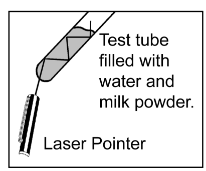

Figure 7.

APPLICATIONS AND DEMONSTRATIONS

Observing Internal Reflections in a Curved Water Jet

Punch or drill a 5 mm hole near the bottom of an empty 1 liter clear plastic soda bottle. Aim the beam of a laser pointer so it goes into the bottle and out the hole. Fill the bottle with a mixture of water and milk powder. Notice that as the water emerges from the hole, the laser beam will follow the water jet as it arcs downward. This illustrates the internal reflections that take place in a fiber optics cable.

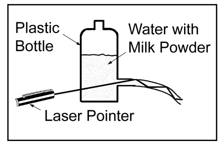

Figure 8.

Viewing Frosted Light Bulb Filaments

Aim the laser pointer through the side of a frosted incandescent light bulb. The frosting of the bulb scatters the laser beam and a clear shadow of the filament appears on the opposite side of the bulb. Any break in the filament of a defective bulb will be clearly visible using this technique.

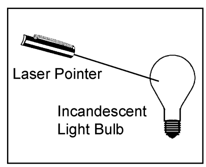

Figure 9.

It is also interesting to try the same thing with a fluorescent lamp tube. Aim the laser pointer beam through the phosphors near the ends of the tube. The shadows of the internal electrodes are projected on the tube by the scattered light.

APPLICATIONS AND DEMONSTRATIONS

Curving a Laser Beam

A laser beam can be made to curve if its transmission medium has gradual changes in its optical density (refractive index). This can be observed by partially filling a fish tank with clear water and adding a few lumps or cubes of sugar. Allow the sugar to dissolve undisturbed. After a few hours you will have a sugar solution that is dense at the bottom, but gradually becomes less dense toward the surface. A horizontal beam from the laser pointer will bend into a curve as it encounters changes in the index of refraction of the transmission media.

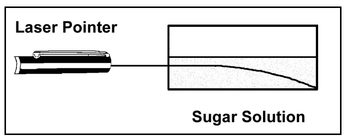

Figure 10.

This principle is used in the construction of fiber optics cables. The inner core of the fiber has a greater index of refraction than the outer layers. Light rays that try to leave the fiber optics cable through the sides of the cable are bent back toward the central core.

The same principle is also used in the construction of your laser pointer. Photons are produced when electrons meet holes in the active layer of the laser diode chip. The semiconductors that are above and below the active layer have decreasing indexes of refraction. Any light rays that attempt to escape are bent back into the main channel where they reinforce the laser action.

APPLICATIONS AND DEMONSTRATIONS

Deflecting the Laser Beam with Voice

Remove the top and bottom of a coffee can. Stretch a section of balloon rubber over one end of the can and secure it with a rubber band. Glue a piece of lightweight mirror near the center of the rubber. Adjust the position of the can so the mirror reflects the beam toward a distant wall. Speaking or singing into the open end of the can vibrates the stretched rubber causing beam deflections on the wall.

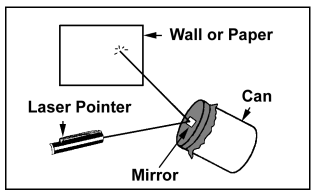

Figure 11.

Laser Light Music Show

Connect an external speaker to a radio. This can be done by removing the internal speaker and reconnecting it to the original terminals of the radio with longer wires.

Glue a lightweight mirror near the center of the speaker cone. Then aim your laser pointer at the mirror so that the beam's reflection falls on a distant wall. When the radio is tuned to a lively station, the speaker vibrations will form patterns on the wall. These patterns keep time with the music.

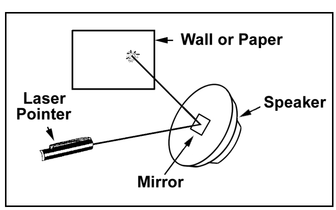

Figure 12.

APPLICATIONS AND DEMONSTRATIONS

Cutting the Laser Beam with a Comb

To create a sound that mimics the sawing of wood, first aim the laser pointer at the solar cell included in the education kit. Then set up an audio amplifier and speaker near the solar cell. Connect two short wires to the terminals of the solar cell. Connect the other ends of the wires to a plug that fits in the microphone jack of the amplifier.

Moving the teeth of the comb back and forth across the laser beam interrupts the light reaching the solar cell. This will cause sounds to be emitted from the speaker. The faster the movement of the comb, the higher the pitch will be of the sound emitted from the speaker.

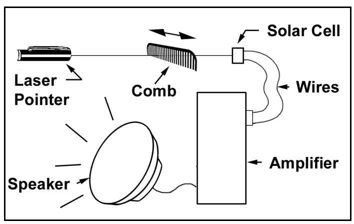

Figure 13.

Exercising Your Dog or Cat

This application is a bit frivolous but it usually works and might possibly be useful to someone. After the sun has set, aim your laser pointer so it makes a small moving spot on the grass or on some bushes. When you move the beam about, many dogs (and some cats) will attempt to catch the spot.

Caution! ⚠ Never aim the laser beam directly into an animal's eyes.

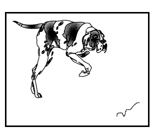

Figure 14.

EXPERIMENTS

Experiment 1 – Investigating Paired Muscle Balance

Discussion

It is difficult to extend your arm horizontally and hold it steady. When you try, paired flexor and extensor muscles in your arm take turns contracting and relaxing. Although it is impossible to hold your arm absolutely steady, some people are much better at it than others.

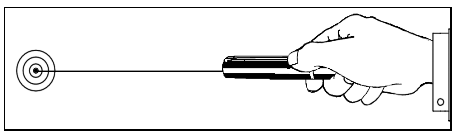

Figure 15.

Procedure

1. Extend your arm horizontally and aim the laser pointer at the bull's eye of a small target that is at least 7 meters away.

2. Ask someone to watch the target and measure the longest time that the laser beam could stay inside the bull's eye of the target. If the time is only a second or less, try measuring the longest time for the beam to stay within the inner two circles or the inner three circles of the target.

3. Compare the scores achieved by your classmates or others who volunteer to take the steadiness test. See if there is any correlation of scores on the steadiness test with age, sex, time of day, or other factors that you can think of that might affect a person's steadiness.

EXPERIMENTS

Experiment 2 – Ophthalmology

Discussion

The spot produced by an enlarged laser beam appears to be filled with many small dots or grains. This granular appearance is an interference pattern created in space by reflections from the illuminated area. When the spot is observed closely and you shift your head to the left, the grains appear to move toward the left or the right. The directions that the grains appear to move may be used to diagnose certain eye defects.

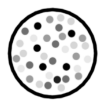

Figure 16.

Procedure

1. In a room with subdued lighting, aim the laser beam at a piece of white paper a few meters away. Expand the laser beam using the lens furnished with the laser pointer education kit.

2. Observe the illuminated area and notice that there are many small dots or grains in the spot. Move your head very slowly from side to side while observing the spots. If you are farsighted, or if your eyes are normal, the small dots will appear to move in the same direction as your head. If you are nearsighted, the dots will appear to move in a direction opposite to that of your head. In nearsighted people, the eye tends to focus the pattern a short distance in front of the retina. Therefore, the parallax caused by the head movement results in an apparent motion of the dots in the opposite direction.

3. Demonstrate the parallax effect by holding your fingers a few centimeters apart in front of your eyes. Look at an object on a distant wall. Your fingers represent the interference pattern and the distant object represents the laser beam spot. When your head is moved slowly from side to side, your fingers appear to be moving in the opposite direction.

EXPERIMENTS

Experiment 2 – Ophthalmology

4. Simulate myopia (nearsightedness) with the aid of the long focal length lens from your laser pointer education kit. With the lens held in front of one eye, move your head slowly from side to side while observing the movement of the dots produced by the laser beam. Record the results.

5. Simulate hyperopia (farsightedness) by observing the laser beam dots through the short focal length lens of the laser pointer kit. Move your head slowly from side to side and record your results.

6. If you normally wear eyeglasses, check your eyes in the manner described above with and without your corrective lenses. Record your results.

EXPERIMENTS

Experiment 3 – Specular and Diffused Reflection

Discussion

In this experiment two kinds of laser beam reflections, specular and diffused will be investigated. Specular reflections are continuations of the original light rays, but in a different direction. Diffused reflections are scattered and travel in many different directions after they strike the reflecting object.

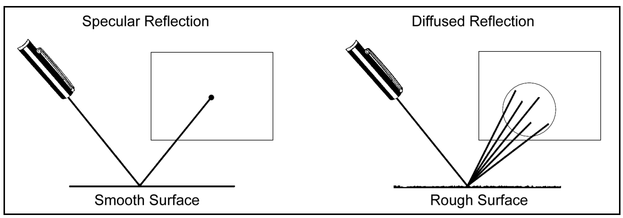

Figure 17.

Procedure

1. In a darkened room, aim your laser pointer at an object with a rough texture such as a woolen cloth or rough piece of wood. Observe the spot of light that appears on a sheet of white paper that is held to catch the reflections.

2. Repeat Step 1 substituting an object of the same color but with a smoother texture for example a silk cloth or very smooth piece of wood.

3. Substitute a variety of other objects that are readily available. Observe the light that is reflected by each.

4. Record your observations and conclusions. In each case record the type of material and the appearance of the reflected laser light.

EXPERIMENTS

Experiment 4 – Reflection and Absorption

Discussion

Whenever red laser light strikes an object, some of its energy will be reflected and some will be absorbed. In this investigation, you will observe how red laser light is reflected off a glossy page printed in four colors.

Procedure

1. Select a large four-color picture. Aim your laser pointer at a white portion of the illustration. Note the intensity of the reflected light from this illuminated area. Repeat this by aiming your laser pointer at different portions of your illustration (such as a red area, blue area, yellow area, and black area). In each case record the relative intensity of the reflected laser beam.

2. When you have observed each area of the illustration several times, summarize your observations and state your conclusions.

3. For research projects to determine the reflectivity of different surfaces or colors use a calibrated laser power meter such as Industrial Fiber Optics' Laser Power Meter 45-545A.

EXPERIMENTS

Experiment 5 – Verifying Law of Reflection

Discussion

The law of reflection states that the angle of incidence is always equal to the angle of reflection. Verify this with your laser pointer and optics components in your laser pointer education kit.

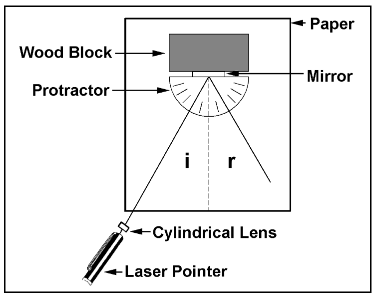

Figure 18.

Procedure

1. Fasten one of your front surface mirrors to the side of a wood block as shown in the diagram. Make sure that the mirror's surface is kept very clean.

2. Place the wood block near the top of a sheet of paper then place a protractor on the paper so the base line of the protractor is directly under the bottom edge of the mirror.

3. On the paper, construct a normal to the mirror surface. This is shown as a dotted line that makes an angle of 90 degrees with the mirror.

4. Aim the beam of your laser pointer at the mirror. Insert the cylindrical lens in the laser beam so it spreads out the light. Red lines showing the directions of the incident and the reflected rays will appear on the paper.

EXPERIMENTS

Experiment 5 – Verifying Law of Reflection

5. Measure and record the size of the *angle of incidence* (i). This is the angle between the incident ray and the normal.

6. Measure and record the size of the *angle of reflection* (r). This is the angle between the reflected ray and the normal.

7. Change the positions of your laser pointer to create several additional angles of incidence. For each angle of incidence, measure and record the corresponding angle of reflection.

Conclusions

Examine your data. It is likely that your data will show that the corresponding angles of incidence and refection are not exactly equal in every case. Account for your experimental errors.

Experiment 6 – Measuring the Index of Refraction of Glass

Discussion

When a beam of light crosses the boundary between air and glass, its speed and direction change. The change of direction, called *refraction*, depends on the relative speed of light in the two media. By measuring the change in the direction of a laser beam as it travels from air to glass, we can calculate its index of refraction. This index is based on the ratio of the speed of light in glass with respect to that in a vacuum. However, since the speed of light in air is very close to that in a vacuum, there is only a small error in using air rather than a vacuum as the reference medium.

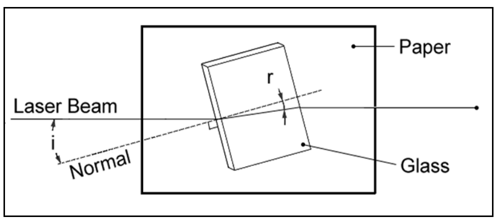

Figure 19.

Procedure

1. Place a rectangular glass prism in the center of a sheet of paper and carefully trace its outline on the paper.

2. Aim your laser pointer so its beam just grazes the surface of the paper and enters the glass at an angle as shown in the diagram above. If this is done correctly, a bright red line will appear on the paper as the laser beam enters the glass. A second line will appear as the beam leaves the glass.

3. With the aid of a sharp pencil and a straight edge, trace the path of the laser beam on the paper. Be especially careful to mark the points where the beam enters and leaves the glass.

EXPERIMENTS

Experiment 6 – Measuring the Index of Refraction of Glass

4. Remove the glass prism and draw a line on the paper to show the path of the laser beam when it was inside the prism.

5. With the aid of a protractor, construct a dotted line on the paper to show the *normal* to the glass edge at the point of beam entry.

6. On your paper, label the *incident* and *refracted* rays at the point of beam entry.

7. At the point of beam entry, measure the *angle of incidence* θ_i. This is the angle between the *incident ray* and the *normal*. Also, measure the *angle of refraction* θ_r the angle between the *refracted ray* and the *normal*.

8. Refer to the Snell's Law equation below. Knowing that the *index of refraction* of air (n_{air}) is 1.00, solve for the *index of refraction* of glass (n_{glass}).

$$n_{air}\sin\theta_i = n_{glass}\sin\theta_r$$

9. Using a slightly different angle of incidence, repeat Steps 1 through 8.

EXPERIMENTS

Experiment 7 – Measuring the Speed of Light in Water

Discussion

In a vacuum all light travels at the same speed, 3.00×10^8 m/s. In other media light travels slower than it does in vacuum. Its speed depends on the color of the light and the optical density of the medium.

In this experiment, you will determine the speed of red laser light as it travels through water. This can be done by comparing the distance that beams from two laser pointers cover during the same interval. One, as it is traveling through air, and the other, through water. Recall that the speed of the light in air is almost the same as that in vacuum, 3.00×10^8 m/s.

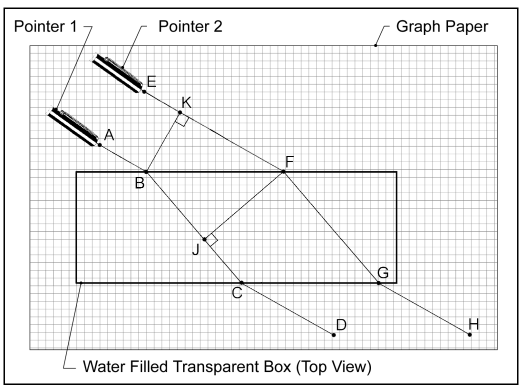

Figure 20.

Procedure

1. Place a transparent plastic box over a sheet of graph paper on a table. Partially fill the box with water and add a pinch of powdered milk to make the water a bit cloudy.

Experiment 7 – Measuring the Speed of Light in Water

2. Position two laser pointers about 5 cm apart on the table. Aim them so the beams are parallel and enter the side of the box at an angle of about 20 degrees. Observe how the direction of the laser beams change as the light enters the box and as the light leaves the box.

3. On your graph paper, place four dots (A, B, C, and D) to mark the path of the first laser beam. Place four additional dots (E, F, G, and H) to mark the path of the second laser beam.

4. Remove the box and connect the dots on the graph paper to show the zigzag paths of the beams from the time that they leave the laser apertures until they exit the box.

5. On your graph paper construct a perpendicular from point F to line BC. Place a dot (J) where the perpendicular intersects the line.

6. Construct a second perpendicular from point B to line EF. Place a dot (K) where the perpendicular intersects the line.

7. Calculate the speed of light in water (v_{water}) using the ratio:

$$\frac{v_{air}}{v_{water}} = \frac{KF}{BJ}$$

8. Change the angle that the laser beams enter the water. Repeat steps 2-7.

   Note: BJ is a distance that one beam traveled in water. During the same interval, light from the second laser was able to travel a longer distance (KF) through air.

EXPERIMENTS

Experiment 8 – Measuring Laser Beam Wavelength

Discussion

The red light that is emitted by your laser pointer consists of waves that are shorter than a millionth of a meter. Because of microscopic differences in laser diode crystals, the wavelength of a particular laser pointer can only be specified to within about $\pm$ 10 nanometers. Most common red diode lasers emit laser light at around (to within $\pm$ 10) 635, 650 or 670 nanometers.

In this experiment, you will measure the precise wavelength of your laser pointer. It will be done using the classic interference technique developed by Thomas Young in 1801.

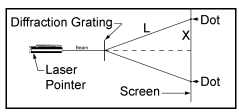

Figure 21.

Procedure

1. Aim the laser pointer so its beam is perpendicular to the center of a screen.

2. Place a diffraction grating in front of the laser. This produces a series of dots (interference antinodes) on each side of the centerline.

3. Measure the distance X This is one-half the distance between the two dots closest to the centerline.

4. Measure the distance L. This is the distance between the point where the beam leaves the diffraction grating and a dot closest to the centerline.

5. Record distance d, the known distance between slits on your diffraction grating (1.33 x 10^{-6} m for grating supplied with kit).

6. Calculate the wavelength lambda (λ) using the following equation:

$$\lambda = d \frac{X}{L}$$

Experiment 9 – Polarization Effects

Discussion

Unlike the light from the sun or from an incandescent lamp, the beam of your laser pointer is partially polarized. A measurable portion of the laser light is vibrating in one plane while the vibrations of the rest of the light are distributed among other planes perpendicular to the laser beam path. The presence of polarized light can be detected with a polarizing filter. It has a crystalline structure that allows waves vibrating in line with the crystals to pass while restricting waves that vibrate in other planes.

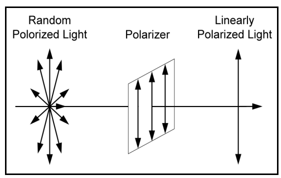

Figure 22.

Procedure

1. Aim a flashlight beam through a Polarized filter at a white screen. Rotate the Polarized filter and observe that there is no perceptible difference in the brightness of the spot on the screen. Substitute the laser pointer for the flashlight and repeat the procedure. Observe the variations that occur in the spot's intensity, as the filter is rotated 360 degrees. Maximum intensity is observed when the plane of the laser beam vibration is aligned with the crystals in the filter. When the alignment is offset by 90 degrees, the intensity of the spot is reduced to a minimum.

Experiment 9 – Polarization Effects

2. Aim the laser pointer at a white screen through a Polarized filter. Rotate the filter until the beam intensity is at its maximum. Then rotate a second Polarized filter in the laser beam and observe the intensity variations that occur. Repeat this procedure using a flashlight in place of the laser pointer. Compare your observations with those in Step 1 above.

3. Fill a test tube with water and add a pinch of milk powder to scatter any light that enters the tube. Aim your laser pointer so its beam enters the mouth of the tube and continues through its center. Observe the intensity of the scattered light by looking at a side of the tube through a Polarized filter. Observe the intensity variations in the scattered light as the laser pointer is rotated slowly about its long axis.

THEORY OF LASER POINTER OPERATION

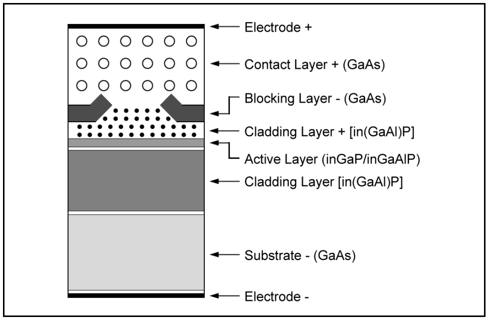

Figure 20. Index-Guided Visible Laser Diode (VLD), Schematic Structure

Properties of Semiconductors in the Laser Chip

Laser action, which produces the red beam of the laser pointer, is generated in a tiny channel sandwiched between semiconductors. Typical dimensions of the laser chip are roughly one or two millimeters. The active layer where light is emitted is only a few microns thick.

The laser chips are built on a slice of gallium arsenide crystal that is about 0.5 mm thick. This gallium arsenide is an n-type semiconductor that has a surplus of mobile electrons within the crystal lattice.

Impurities are added in sequence to the surface and diffuse into the gallium arsenide crystal to form p-type semiconductor layers. These impurities capture electrons and leave holes in their place. We may think of the holes as carriers of positive charge because they move in the same direction as positive charges under the influence of an electric field. The schematic structure diagram shows the arrangement of the semiconductor layers that comprise the laser.

Photon Production

Applying a forward bias of 2-3VDC to the laser electrodes creates an electric field across the semiconductors. With sufficient energy both electrons and holes are injected into the active layer.

THEORY OF LASER POINTER OPERATION

When an electron and a hole meet, they annihilate each other and release energy to produce a photon of red light. By itself, a photon does not create much light. But, together with the combined energy of many others of the same wavelength, an intense laser beam is produced.

Index-Guided Photon Enhancement

Photons, created in the active area of the laser, stimulate other electron-hole pairs to meet, annihilate, and produce additional photons of the same wavelength, phase, and direction. Upon reaching the ends of the crystal, most of the photons emerge to form the laser beam. However, about 36% of the photons are reflected back into the active layer by a pair of flat cleaved ends at opposite sides of the laser diode. They enhance further stimulation of electron-hole pairs.

Other photons may travel toward the sides of the diode crystal instead of going in the desired direction toward the laser aperture. To minimize this loss, the semiconductors that comprise the laser are arranged so their indices of refraction decrease with distance form the main channel. As the index of refraction becomes lower, stray photons are bent away from the normal and many are guided back into the main channel.

LASER BEAM CHARACTERISTICS

The beam emitted from the aperture of a diode laser pointer differs from that of a helium-neon laser in three significant ways; the shape, visibility, and coherence length.

Beam Shape

Because the beam comes from an end of a rectangular slab rather than a round capillary tube, the beam is emitted with an elliptical cross section. In a diode laser pointer this is corrected with collimating optics.

Beam Visibility

A wavelength of 670 nm lies in the deep red portion of the spectrum. The human eye is much less sensitive to this wavelength than it is to the shorter wavelength of bright red light.

Therefore, the beam from a 670 nm diode laser appears to be only one-quarter as bright as that of a 635 nm diode laser or a helium-neon (632.8 nm wavelength) beam. However, a silicon diode solar cell is more sensitive to the deep red light from a 670 nm pointer than it is to the bright red beam of the HeNe laser.

Beam Coherence Length

Beam coherence length is the distance that the laser beam can travel while its photons remain in phase with each other. A long coherence length is essential for alignments in interferometry or holography set-ups.

Many laser pointers have coherence lengths that are 5 cm or more. A longer coherence length makes it possible to use a laser pointer for holography and interferometry without worrying too much about highly precise placements of optical components.

Wavelength

Red diode laser pointers produce beams at wavelengths of approximately (to within ± 10 nanometers) 635, 650 or 670 nanometers. The wavelength depends on the geometry and composition of the individual laser crystal and also upon the operating temperature to some extent. The crystals are mounted on metallic heat sinks for thermal stability and are surrounded by metal shielding to resist damage from rough handling and static electricity.

Laser Beam Power

Power is related to the intensity of the laser beam and is measured in milliwatts. The output power of a laser pointer usually ranges between 0.8 to 0.9 mW (Class II) and 2.5 to 3 mW (Class IIIa) when a set of fresh alkaline batteries is first installed. As the batteries age, the output power of the laser beam can be expected to gradually decline about 30 percent during the first four hours of constant operation and another 20 percent during the next eight hours. Thus, after 12 hours of constant operation you can expect the output power of the laser beam to be reduced by approximately 50 percent.

DAMAGE OR LOSS IN SHIPMENT

If damage to an Industrial Fiber Optics product should occur during shipping, it is imperative that it be reported immediately, both to the carrier and the distributor or salesperson from whom the item was purchased. DO NOT CONTACT INDUSTRIAL FIBER OPTICS.

Time is of the essence because damage claims submitted more than five days after delivery may not be honored by the carrier. If damage has occurred during shipment, please do the following:

- Make a note of the carrier company; the name of the carrier employee who delivered the damaged product; the date; and the time of the delivery.
- Keep all packing material.
- In writing, describe the specific nature of damage to the product.
- In cases of severe damage, do not attempt to use the product (including attaching it to a power source).
- Notify the carrier immediately of any damaged product.
- Notify the distributor from whom the purchase was made.

RETURN POLICY

Before returning any item to Industrial Fiber Optics, you must first contact our office to get a Return Merchandise Authorization (RMA) number. A copy of the RMA Invoice will then be faxed to you. Returns must be shipped freight prepaid and be well packed. We are not responsible for items damaged in transit back to us. Include a copy of the faxed RMA Invoice, along with a brief explanation as to the reason for the return. Please state whether you are requesting an exchange, a repair, or a refund.

Rules for Laser Safety

- Lasers produce a very intense beam of light. Treat them with respect. Most educational lasers have an output of less than 3 milliwatts, and will not harm the skin.
- Never look into the laser aperture while the laser is turned on! **PERMANENT EYE DAMAGE COULD RESULT**.
- Never stare into the oncoming beam. Never use magnifiers (such as binoculars or telescopes) to look at the beam as it travels — or when it strikes a surface.
- Never point a laser at anyone's eyes or face, no matter how far away they are.
- WHEN using a laser in the classroom or laboratory, always use a beam stop, or project the beam to areas which people won't enter or pass through.
- NEVER leave a laser unattended while it is turned on — and always unplug it when it's not actually being used.
- REMOVE all shiny objects from the area in which you will be working. This includes rings, watches, metal bands, tools, and glass. Reflections from the beam can be nearly as intense as the beam Itself
- Never dissemble or try to adjust the laser's Internal components. Electric shock could result.