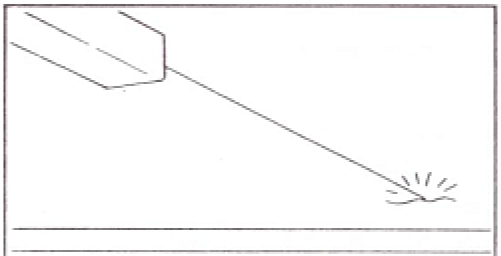
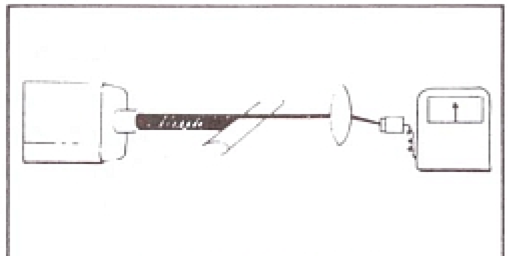
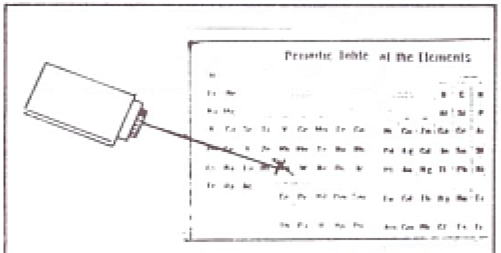
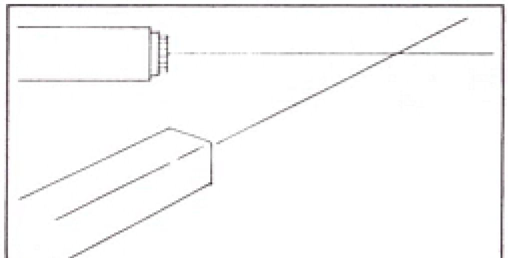
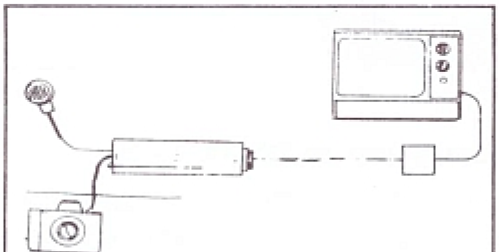
More Than 101 Ways to Use a Laser

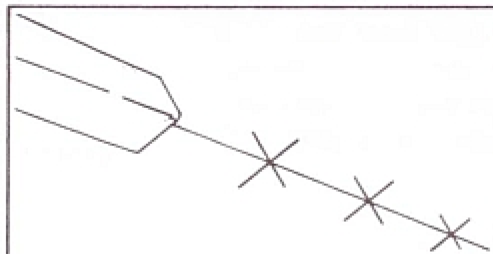

Detect flaws, scratches.

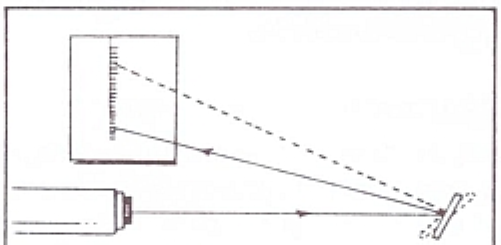

Inspect wobble, height.

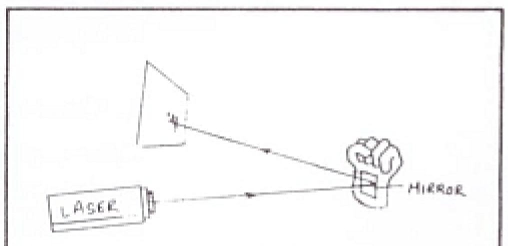

Pin point a target.


Pinpoint distance.

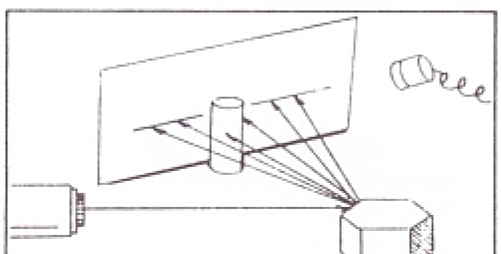

Communicate, audio or video.

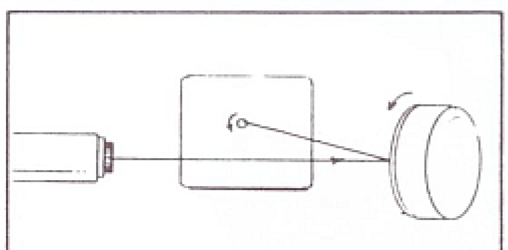

Position and level objects.

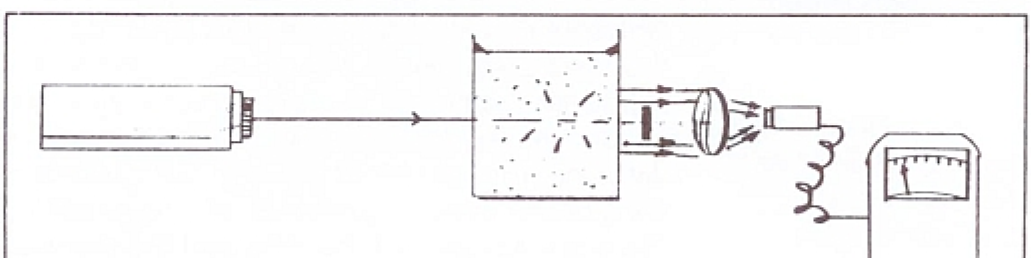

Magnify changes.



Monitor pulse.


Measure by scanning.


Align wheels, rotating shafts.

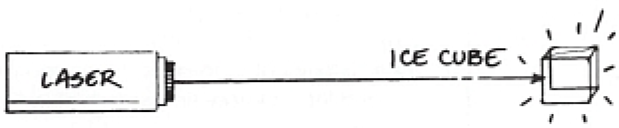

Monitor purity.

1. Scattering, Beam Visibility in Air

Shake chalk dust in the laser beam path. The beam is invisible in a dust free room but the particles scatter the light enabling us to "see" it. This demonstration is most effective in a completely darkened room. Although chalk dust is very effective, it can harm computers and other electronic apparatus in a science classroom. You can substitute most aerosol sprays and fog from cold-mist humidifiers. But avoid hair sprays and similar materials which can clog the lungs.

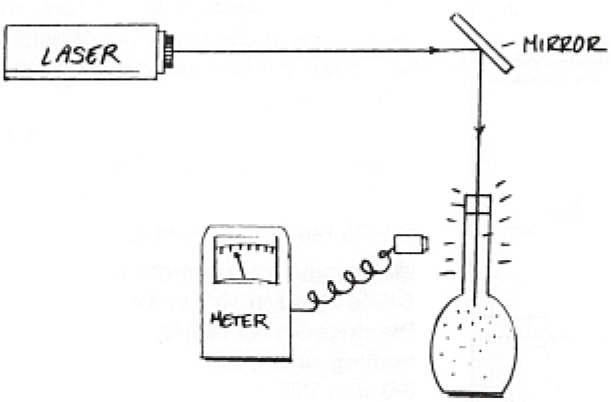
2. Scattering, Crystal Imperfection

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



3. Scattering, Rayleigh Effect

Mix a few drops of silver or gold nitrate in a florence flask filled with water. Polarize the laser beam by placing polaroid film over the front of the laser and aim the beam down into the neck of the flask. Using a laser power meter, observe the changes in the intensity of the scattered, polarized light when the meter is moved in a 360 degree circle around the flask.

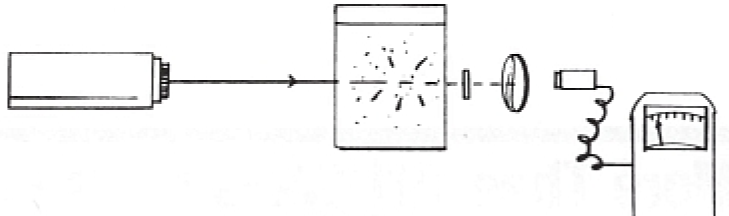


4. Scattering, Size of Particles

Use the same set up as the Rayleigh Effect above. Substitute a few drops of milk for the nitrate. Since the particles of milk are larger than the wavelength of the laser light, they produce a more complicated scattering pattern than that produced by the Rayleigh Effect.

5. Scattering, Monitoring Fluid Purity

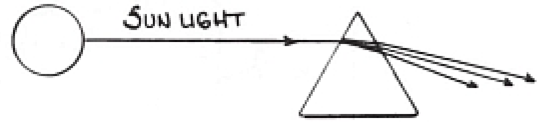
Shine the laser beam through a flat-sided glass container filled with a transparent gas or liquid. Place a laser power meter on the other side of the container. Place a small opaque object and a larger converging lens in front of the meter detector. This will block the direct beam and focus any scattered light into the detector. As increased amounts of colloidal particles are placed in the container, additional light will be scattered from the main beam. High readings on the power meter indicate high pollution.

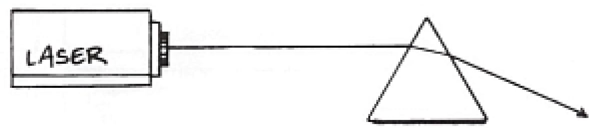


Monitor purity.

6. Color, Monochromaticity of Laser Light

Form a narrow beam of white light by letting sunlight pass between two razor blades. Allow this beam to pass through the prism.
A spectrum of colors will appear. Do the same with neon laser light. Since there are no prominent wavelengths other than red, the laser light cannot be divided into colors. (To be precise, it must be stated that most lasers are not truly monochromatic. Metrologic lasers, for instance, produce several closely related wavelengths.)



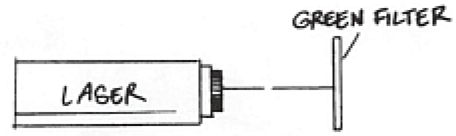


7. Color, Absorption of White Light

Color filters absorb certain wavelengths, while allowing light of other wavelengths to pass relatively uneffected. Hold filters of various colors in front of your eyes and view objects in the room (not laser beams). Objects appear dark or black ("absence of light") when their color is absorbed.

8. Color, Absorption of Laser Light

Filters can act as selective absorbers of light. A filter will transmit some colors and absorb others. Most green filters are strong absorbers of red laser light. Some colors are transmitted and others absorbed. Try some experiments using colored cellophanes or colored plastics.

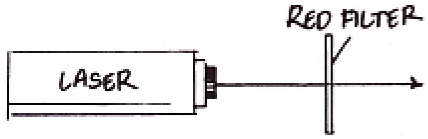


9. Color, Quantum Energy of Red Light

Shine ultraviolet light on a zinc plate attached to an electroscope that has been given a residual negative charge. Compare the response with that of a demonstration in which the red laser beam is used as the light source. The electroscope discharges immediately with the application of the dim ultraviolet light, but the intense red light of the laser beam does not have sufficient energy to overcome the work function of the zinc and the electroscope will not discharge.

10. Color, Coefficient of Absorption

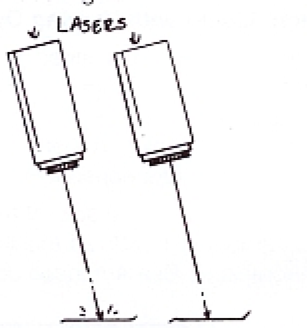
The thicker the filter, the greater the absorption. Find a homogeneously colored glass that has several thicknesses. Shine a laser beam through each of the thicknesses and record the poser output using a laser power meter. Plot the power output versus the thickness. The poser output should vary in an exponential manner. For details, refer to the Beer-Lambert Law.



Using inexpensive color filters, it is relatively easy to separate the red laser light from the other wavelengths of "white" light. Consider the bar code scanner used in supermarkets. Only a tiny portion of the original laser beam is reflected from the symbol on the package back to the photodetector. This small amount of light is separated from ambient light with a red color filter. The red light passes through the filter. The red light passes through the filter and is bright to the detector, but the background is dark.

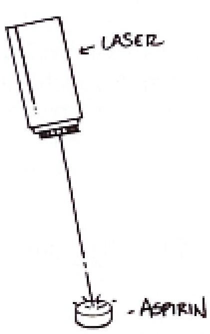
11. Color, Reflection from Opaque Surfaces

Opaque materials selectively reflect different colors. Show this by expanding the width of the laser beam to about one inch with a diverging lens. Hold paper of various colors within the beam. Observe how some reflect the light better than others. Consider problems of a designer who must plan bar code symbols for grocery packages. If the bars are to be printed with black ink, the background color of the package must appear bright when illuminated with red laser light.



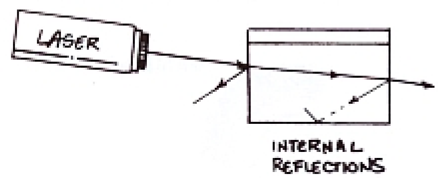
12. Reflection, Specular Versus Diffuse

Objects such as mirrors provide specular reflections. That is, they change the direction of the beam without scattering or diffusing the light. Rough objects provide diffuse reflections that scatter the light. Shine the laser at various objects, and plot the reflection strength vs. angle. See how an aspirin reflects nearly 100% of the light over a large angle.



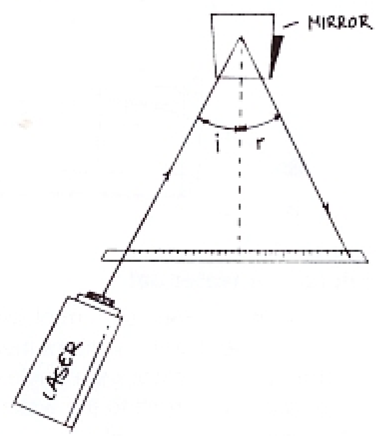
13. Reflection, Internal Reflections

Shine the beam into a tank of water and observe that the light will be reflected not only when the beam enters the water, but also when the beam is leaving from a different side of the tank. Reflections that tend to keep the laser beam inside of the medium are known as internal reflections. The intensity of these reflections vary with the angle of incidence as the beam attempts to leave the medium. See if you can observe a secondary spot that a laser will generate off to the side of the main beam. This unwanted spot is caused by reflections inside the glass of the laser's front mirror.



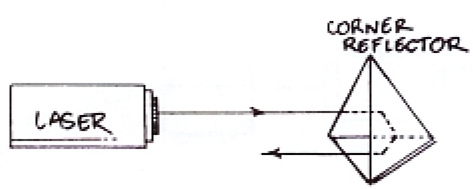
14. Reflection, Law of Reflection

The Law of Reflection states that the angle of incidence is equal to the angle of reflection and that the incident ray, normal, and reflected ray all lie in the same plane. Aim the laser toward a distant mirror. Adjust the mirror so that the beam returns to the laser aperture. Move the laser two meters to the right of the original position. Slightly elevate the laser while aiming it at the same spot on the mirror. Determine the relationship between the distance that the laser was elevated and the distance that the reflected beam is depressed.



15. Reflection, Corner Prisms

A corner prism can be made by cutting off a corner of a box and gluing mirrors to the three inner surfaces of the corner. Hold a flat mirror about 5 meters from the laser and try to reflect the beam back into the laser aperture. See how much easier this can be done with a corner reflector. The American astronauts put corner reflectors on the moon. Now timed laser pulses from the earth can be returned to their origin whenever it is necessary to make precise moon-earth distance measurements.

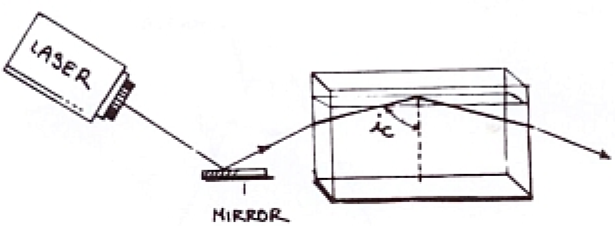


16. Reflection, The Colors of the Rainbow

Direct a low-power laser into a glass cylinder filled with water. Add two or three drops of milk or powdered cream to the water to make the beam visible. By moving the cylinder slowly across the laser beam, the internal reflections and refractions will be visible. The intensity of the emerging beam will vary as the angle of incidence between the laser beam and the cylinder is changed. The angles between the incident and emerging beam can be measured using long distance techniques and a laser. Measurements can be related to Sir Isaac Newton's explanation of the "Causes of Colors in the Rainbow." (See Metrologic's "Experiments Using a Helium-Neon Laser" for Newton's explanation.)

17. Reflection, Critical Angle

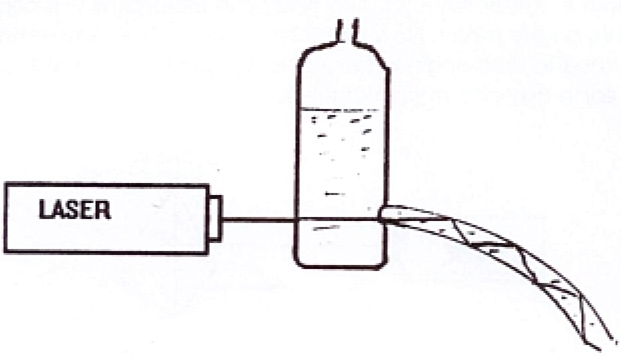
Position a laser so that the beam enters the side of a fish tank and emerges from the top. Fill the tank with water and a few drops of milk to make the beam visible. Then decrease the angle that the laser beam in the water makes with the surface until it no longer emerges but is totally reflected back into the tank. When this first occurs, the angle between the laser beam and the normal to the surface is called the critical angle of water. To find the index of refraction of water, take the reciprocal of the sine of the critical angel.



18. Internal Reflections in a Water Jet

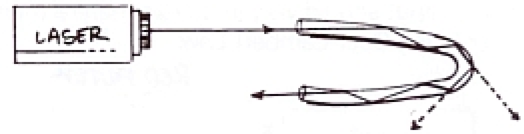
When a laser beam is traveling inside a stream of water, internal reflections at the edges of the jet can prevent the beam from leaving the water. This happens whenever the angle of incidence between the laser beam and the normal to the water surface is greater than the critical angle for water (48°).

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 so it goes into the bottle and out the hole. Fill the bottle with water. When 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.



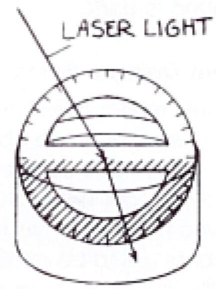
19. Critical Angle, Minimum Radius of Curvature of Light Pipes

As the radius of the bed of a fiber optic light pipe is made smaller, light begins to escape from the sides of the fiber. Determine the minimum radius of curvature for a length of fiber optics or other light guide.



20. Index of Refraction, Liquids

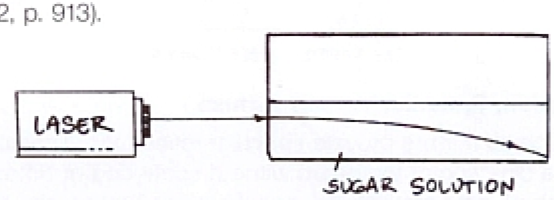
Hold a circular protractor in a vertical position and submerge half of it in a large beaker of liquid. Aim the laser so the beam just grazes the front surface of the protractor and passes through its center. Measure the angles of incidence and refraction. Calculate the index of refraction of the liquid using the relationship $n = \sin i/\sin r$. Repeat for different angles of incidence and for different liquids. Water, alcohol, and glycerin are suitable for this exercise.



21. Index of Refraction, Liquid with Varying Optical Density

If the optical density of a liquid or a gas varies, a light beam will bend gradually as it is transmitted through the fluid. This can be observed by partially filling a fish tank with clear water and adding several lumps or cubes of sugar solution that is dense at the bottom and gradually becomes less dense toward the surface.

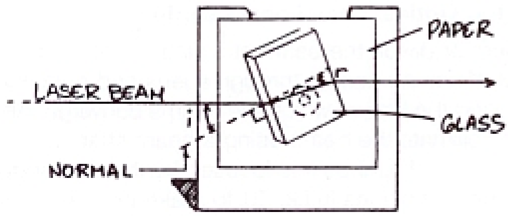
Aim the laser beam horizontally into the side of the tank and observe how the beam gradually bends as the index of diffraction of the sugar solution increases. (See *American Journal of Physics*, July 1972, p. 913).



22. Index of Refraction, Glass

When light travels from air to glass, there is a change of speed and the beam will bend, or refract, at the interface when it enters the glass. Measure the angle (i) between the incident laser beam and the normal to the glass surface. Also measure the angle (r) between the bent beam inside the glass and the same normal. If we assume that the index of refraction of air equals 1, the index of refraction of the glass can then be calculated using Snells Law:

$$n_{air}\sin i = n_{glass}\sin r$$

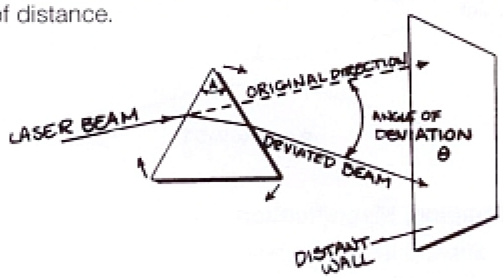


23. Index of Refraction, Prism

When a laser beam is transmitted through a triangular prism, the beam will be refracted twice and emerge along a path that deviates from its original direction of propagation. By rotating the prism, the angle deviation can be made larger or smaller. The smallest angle that can be obtained is called the minimum angle of deviation for the particular prism. By measuring the apex angle of the prism and the minimum angle of deviation, the index of refraction of the prism may be calculated:

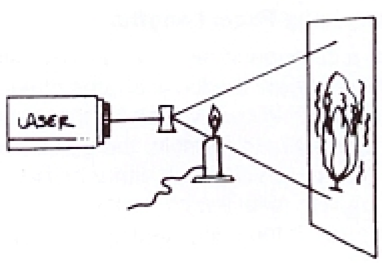
$$n = \frac{\sin 1/2\,(A + \Theta)}{\sin 1/2\,A}$$

Greater precision can be obtained by allowing the beam to cross a room so that small changes in angle will be greatly exaggerated because of distance.



24. Variable Index of Refraction, Schlieren Effect

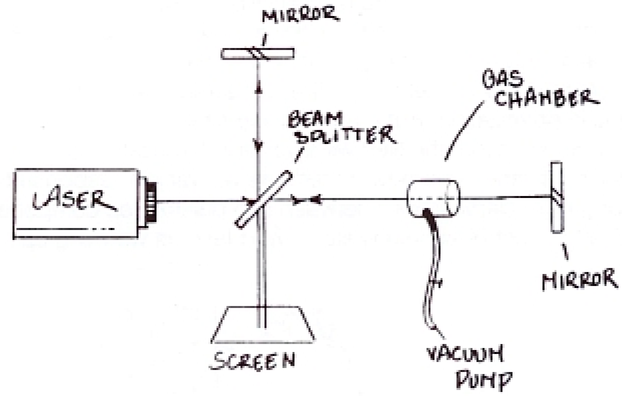
Place the flame of a Bunsen, or propane, burner in an expanded laser beam and observe the image of the flame on a nearby screen. The heated air and rising convection currents cause variations in the index of refraction of the air. This produces moving shadows on the screen, known as Schlieren.



25. Index of Refraction, Gas

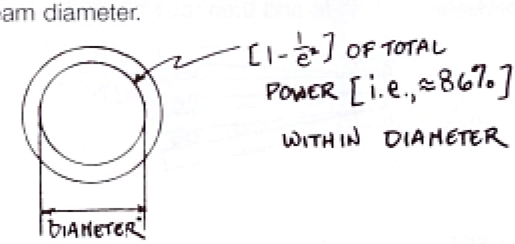
Arrange a Mechelson interferometer with a front surface mirror at one of the arms and a gas chamber mirror combination at the other arm. The light from the laser is split into two beams forming a right angle. After reflection by the mirrors, the beams are superimposed, interfere with each other, and form a series of light and dark fringes on a screen. Use a vacuum pump to evacuate the air in the chamber and then allow air or other gas to return slowly. Air reduces the speed of light and effectively increases the beam path in the gas chamber. Each time the path increases by one wave length, a fringe can be seen to shift on the screen. The index of refraction of air (or any other gas in the chamber) can be determined by using the relationship:

$$n = (2L + n\lambda)/2L$$



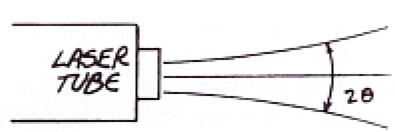
26. Laser Characteristics, Beam Diameter

A laser beam seems larger in a dark room than in a bright one. As a result, the spot size cannot be measured by eye and ruler. By convention, the beam diameter is determined by measuring between the 1/e intensity points. A knife edge (or razor blade) mounted on a calibrated translation stage may be used to measure beam diameter. Read the full beam power with a laser power meter. Move the knife edge into the beam until the power drops to 90 percent of full power. Note the micrometer reading of the stage. Then move the knife edge further into the beam until the power drops to 10 percent of full power. Note the micrometer reading. The difference between the two readings divided by .65 is equal to the beam diameter.



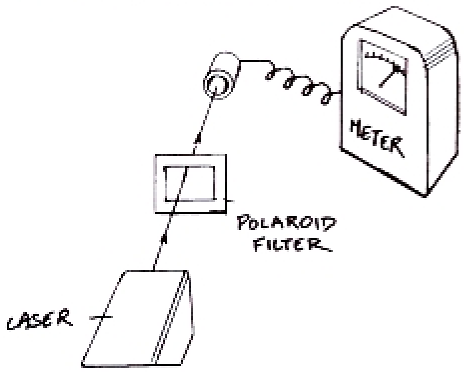
27. Laser Characteristics, Beam Divergence

Divergence, the angle at which the beam expands, is usually measured in milliradians and expressed as the full angle, 2θ. Divergence should be measured several meters from the laser because the function is non-linear close to the laser aperture. To find the divergence in radians, divide the beam diameter by the distance. (e.g., 1.5 cm diameter divided by a 1,000 cm distance equals 1.5 milliradians.)



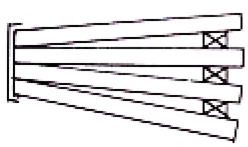
28. Laser Characteristics, Polarization

Helium-neon lasers that do not have Brewster windows at their ends emit light that is randomly polarized. At a given instant, such polarization may be described by two ellipses, each at right angles to the other. Over a period of time, the resultant ellipse will change in orientation and relative magnitude, while maintaining a constant power. Neither power meters nor the human eye can detect these changes in polarization. But if a polarizing filter is placed in front of the laser power meter, the filter will favor one polarization component and block the other. The power readings will vary in response to the changes in relative power between two polarization components. This effect is best observed while a short laser is warming up.



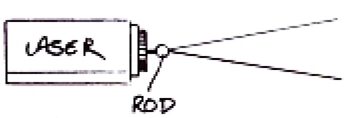
29. Optics, Multiple Beams

A single laser beam can be split into a number of laser beams by directing it through several microscope slides. Tape the sides together on one end. One the other end, wedge a small piece of cardboard between each slide and then tape the slides together.



30. Optics, Cylindrical Lens

A glass stirring rod serves as an inexpensive cylindrical lens. It will spread the beam out so that it forms a line of light rather than a round spot. This technique is used in sawmills to provide a guideline for cutting lumber.

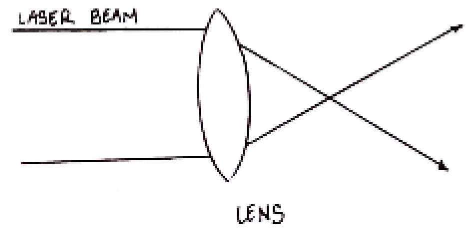


31. Optics, Ray Paths

Use a laser to study geometric optics. Its intense beam indicates ray paths clearly. To make the laser beam visible to a large group, sweep a white card along the beam path. Angle the card toward the viewers. In a container of water, add drops of milk to view the laser beam.

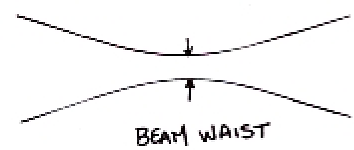
32. Geometric Optics, Lens Focal Length

Use two lasers or divide the beam of a single laser into two parallel components. Pass the beams through a lens and determine the distance beyond the lens at which the beams converge. Alternatively, expand and collimate the beam using a beam shaping telescope. Observe the cone of light as it is focused by the lens under examination. Use the techniques in No. 31 to make the beam visible.



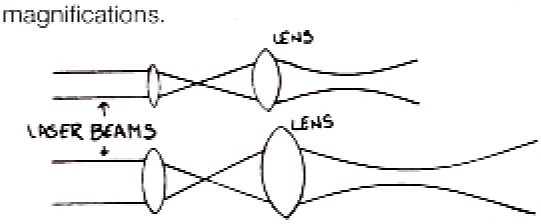
33. Optics, Beam Waist

Wave optics demonstrations of the laser beam waist can be performed by passing the light through a telescope or a pair of lenses so that it focuses at a distance. Wave a card along the beam path and notice how the beam radius narrows as the beam waist approaches. The beam will be symmetrical on each side of the beam waist.



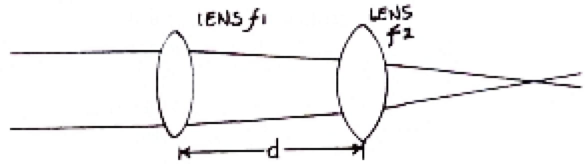
34. Beam Shaping, Magnification

Pair several different lenses to make beam shaping telescopes of several magnifications.



35. Beam Shaping, Lens Focal Lengths

The focal length of a compound lens made of two simple lenses may be predicted if we know the focal lengths of each lens and the distance between them. If known values for these parameters are substituted in the lens maker's formula, the combined focal length of the two lenses may be predicted. If either of the two lenses is divergent, use a negative focal length for this lens when substituting the value in the formula. If the calculated answer comes out with a negative number for the combined focal length, it indicates that the lens system has a virtual rather than a real focus. Check the accuracy of your predictions by putting the lens system in a collimated laser beam.



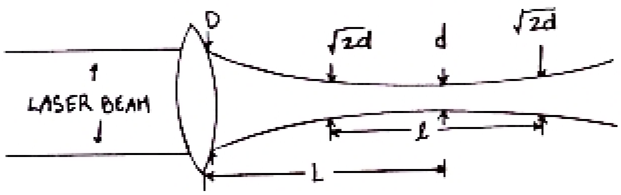
$$1/f = 1/f_1 + 1/f_2 - \frac{d}{f_1 f_2}$$

36. Beam Collimation

Although a laser beam is essentially parallel and does not diverge significantly, over a distance of several hundred meters the amount of spreading becomes significant. To minimize adverse effects of this spreading, collimate the beam. This is done by first spreading the beam with a diverging lens and then making the edges of the beam parallel with a converging lens. By adjusting the distance between the two lenses, the beam can be collimated so it remains at a constant width of about 2 cm over distances of several kilometers.

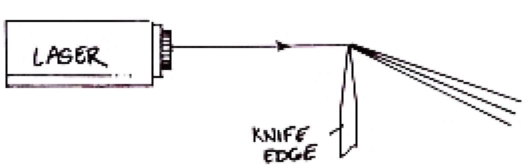
37. Beam Shaping, Depth of Field & Beam Waist Diameter

TEMoo mode lasers have beams that converge to a minimum radius, called the beam waist, and then expand. Collimation is maintained for a short distance in the beam waist that may be called the depth of field. Each end of the depth of field has a diameter that is 1.4 times that of the beam waist. Beyond the end point, the beam begins to diverge and is no longer collimated. If the beam waist is narrow, the depth of field will be short. If the beam waist is broader, the depth of field will be longer. These values are theoretical limits based on l/e^2 diameter and 633 Nm light.



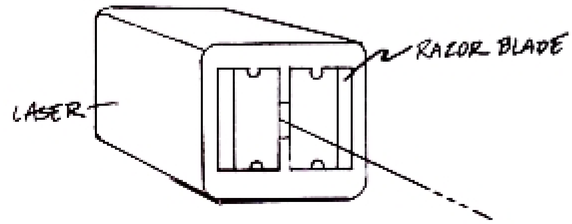
38. Diffraction, Knife Edge

The laser offers convincing proof that light actually bends, or is diffracted, around small objects. Demonstrate knife edge diffraction by pointing the laser at a screen, such as a sheet of glossy white paper, approximately three meters away. Slide the edge of a new razor part way into the laser beam and observe the interference patterns on the screen. Close observation will show that there is no sharp shadow of the edge of the razor blade on the screen, but instead there is a diffraction pattern consisting of a series of light and dark fringes parallel to the edge of the razor blade. Make a graph of the intensity variations of these fringes by moving a photometer across the screen while recording the intensity variations. Compare this graph with the theoretical patterns that can be found in a textbook on optics.



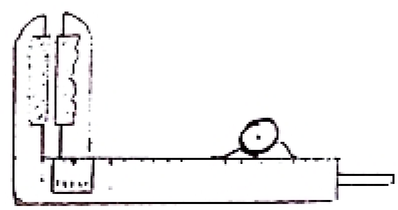
39. Diffraction, Narrow Slit

Using the same setup as for the knife edge diffraction, insert a second razor blade into the other side of the laser beam so that the edge diffraction patterns produced by the two razor blades are superimposed. Observe the effects as the two razor blades are brought closer and closer together to form a narrow slit. Observe the variations in the intensity of the fringes and the distance between them as the razor blades are brought closer together.



40. Diffraction, Variable Slit

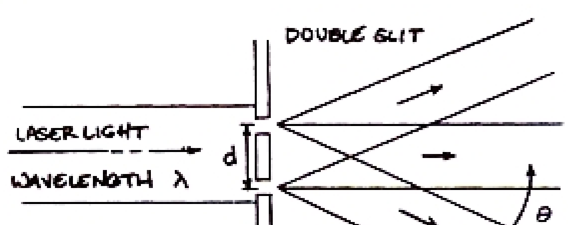
Make an inexpensive variable slit using a vernier caliper and a double edge razor blade. Bend the blade until it snaps along the center and breaks into two halves. Glue or tape each half to a jaw of a bernier caliper as shown in the diagram below. Aim a laser beam at the gap between the blades and observe the single slit diffraction pattern on a distant screen. If the width of the slit is known, the wavelength of laser beam can be determined. Alternately, by using a laser beam of known wavelength, the width of the gap between the jaws can be measured with a high precision.



41. Diffraction, Double slit

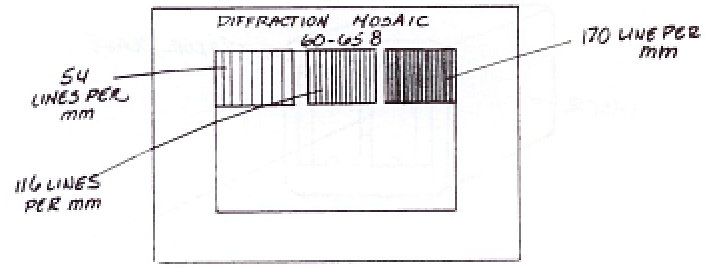
When the laser beam is sent through two narrow parallel slits, each slit produces an identical diffraction pattern. If the slits are close together, the diffraction patterns overlap and a phenomenon called double slit interference occurs.

Investigate the characteristic diffraction and interference patterns as the width and spacing of two slits are varied. Precision double slits for this investigation can be found on the Cornell diffraction slit plate or the Metrologic diffraction slide mosaic furnished with the laser Optics Lab kit. Make a sketch of a typical diffraction pattern and explore the intensity of illumination at various locations the using a photometer.



42. Diffraction, Multiple Slit

When laser light is transmitted through a series of narrow parallel slits that are spaced close together, each slit produces a diffraction pattern which overlaps the patterns produced by the others. If the slits are evenly spaced, a pattern that is very similar to that of the double slit diffraction results, but the additional light coming from the multiple slits produces a much brighter pattern (See *Metrologic's Experiments Using A Helium-Neon Laser*.)



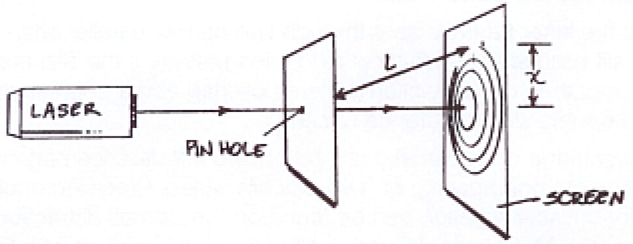
43. Diffraction, Small Holes

Diffraction of a laser beam by a small hole is due to the interference of diffraction fringes from the edges of the hole causing interference in the overlap area.

Make pinholes in a square of aluminum foil using a sharp needle. For better pinholes, pull a sheet of fresh carbon paper through a gap between a tesla spark coil and a ground plate.

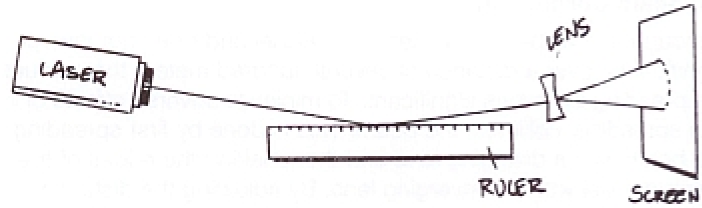
When the laser beam goes through the hole, a bullseye airy disc pattern will appear on a distant screen. If the hole is good, the pattern will be perfectly round.

Experiment making the pinholes smaller. The smaller the hole, the larger the bullseye. Calculate the size of your pinhole by measuring the radius of the Airy disc in the bullseye pattern. Appropriate formulas for this calculation are given in the Metrologic book, *Experiments Using a Helium-Neon Laser*, and in many Optics text-books. The same technique can be used to measure the diameter of a blood cell. (See No. 80).



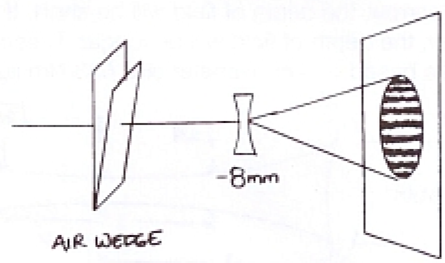
44. Diffraction, Reflections from a Ruler

Diffraction may be observed by reflections from a steel machinist's ruler or an ordinary plastic ruler with fine black markings spaced at millimeter or sixteenths of an inch intervals. Mount the ruler in the laser beam path as shown. The beam should just graze the ruler so that it illuminates approximately three centimeters of the scale. Place a screen about two meters away from the laser so that the diffraction pattern from the ruler may be observed. The pattern will consist of alternate light and dark areas spaced at regular intervals. Small adjustments of the ruler with respect to the laser beam may be necessary to sharpen the pattern. Place a diverging lens in the laser beam at the end of the ruler so that fine details of the diffraction pattern may be observed on the screen. When this has been done, move the ruler slightly while watching the screen. Try to explain why the diffraction patterns change the way they do.



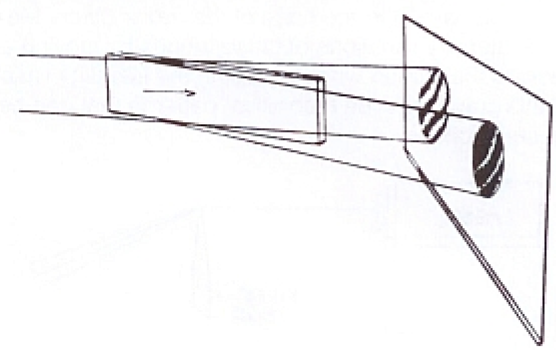
45. Interference, Thin Film

When two sheets of flat glass are separated by a thin film of air, multiple reflections of light occur at the air-glass interfaces. If the thickness of the film is adjusted so that it is ¼ the wavelength of the incoming light (or odd multiples of ¼ wavelength), most of the light will not be transmitted, although air and glass are transparent. Shine a laser beam through the air wedge supplied in the Metrologic Laser Optics Lab kit. Enlarge the beam using a diverging lens and view the resulting interference patterns on a screen. Vary the thickness of the air film edge by squeezing the glass plates together at various places around the edge. Observe changes in the pattern on the screen as the glass is squeezed.



46. Interference, Multiple Internal Reflections in Glass

When a laser beam is transmitted through a flat glass plate, some light is transmitted and some is internally reflected in the glass. As the reflected light subsequently emerges from both sides of the microscope slide at intervals along the surfaces, interference occurs among the multiple beams of coherent light. Interference patterns may be obtained by placing the microscope slide in the beam, as shown in the diagram, so that it is almost parallel to the beam. Try to explain why one of the patterns is the reverse of the other.

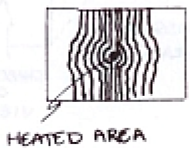


47. Interference, Window Glass

Shine a laser on a piece of glass and allow the reflected light to cross a darkened room. An interference pattern will be observed on the far wall. The fewer and more parallel the interference bars, the more uniform the glass thickness.

48. Interference, Heat Expansion

Touch a soldering iron to the piece of window glass used in the last exercise. A localized distortion of the interference patterns will appear as the glass expands after being heated with the tip of the soldering iron.

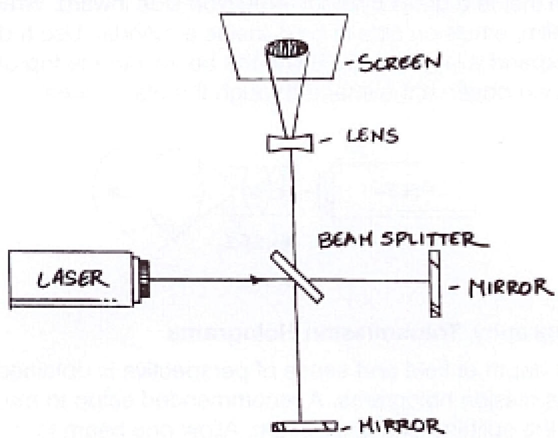


49. Interference, Evaporation of Alcohol

Place a lens within a laser beam and project the enlarged image onto a viewing screen. Place a drop of alcohol on the lens and allow the alcohol to evaporate. As the evaporation proceeds, changing interference patterns will be observed on the screen.

50. Interference, Michelson Interferometer

Dimensional differences less than ¼ wavelength wide can be observed using an interferometer made with a beam splitter, two mirrors, and lens. The beam splitter divides the beam and sends it in two separate directions. Two mirrors return and combine the light. When the light waves combine, they overlap and interfere with each other. When enlarged through a lens and projected on a screen, the canceling effect can be seen as alternate light and dark bands or interference fringes. Observe how the fringes shift when a person coughs or shouts into the apparatus. The beam splitter, front surface mirrors, lens and magnetic holders for the optics components are included in the Metrologic Laser Optics Kit.

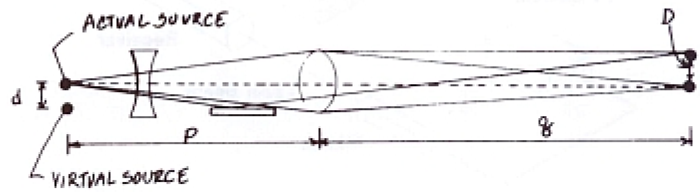


51. Interference, Changes in Volume

Minute changes in volume during heating or cooling can be observed in the classroom. For example, if one of the mirrors in the above experiment is heated with a hair dryer, the fringes will shift. Commercial uses of interferometry include distance, contour, thickness, and flatness measurements; inspection of optical material; determination of the index of refraction of glasses and gases; and examination of dynamic changes in wind tunnels. These applications are especially useful in student research projects.

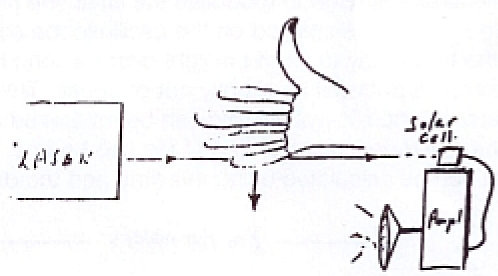
52. Interference, Lloyd's Mirror

Lloyd's mirror is a classic optics experiment and was first described in 1834. Place a converging lens about 10 cm in front of a diverging lens. Shine laser into both. Place a screen about three meters from the laser and adjust the position of the two lenses so that the smallest possible spot can be seen on the screen. Lay a microscope slide between the two lenses. Carefully raise the slide until the laser beam just grazes its upper surface. A second spot will appear on the screen, about one inch above the first. Remove the converging lens without disturbing the other apparatus. With this lens removed, the cones of light coming from the direct and reflected sources partially overlap, forming an interference pattern on the screen. Calculate the wavelength of the laser light using the formula for double slit diffraction. Further details to perform this experiment can be found in the Metrologic book, *Experiments Using Helium-Neon Laser*.



53. Modulation, Morse Code Communication

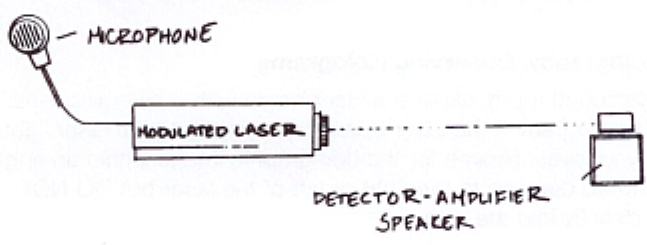
Aim a laser beam at a distant solar-cell photodetector which is connected to the microphone input of an audio amplifier. Whenever the laser beam is interrupted, the amplifier-speaker will produce a loud click. Make a Morse code "dot" by passing your index finger through the laser beam. Make a "dash" by spreading out four fingers on your hand and passing them through the beam at a uniform rate.



54. Modulation, Voice Communication

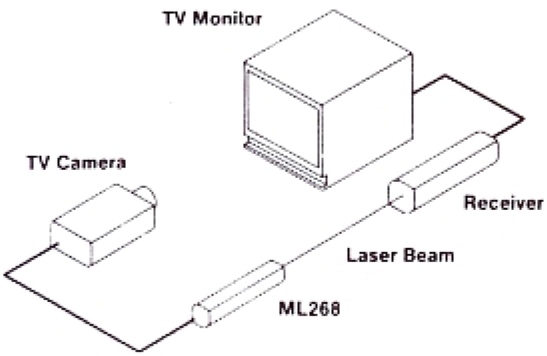
Plug a microphone into a modulated laser. Talking into the microphone alters the laser tube current and the beam brightness varies according to speech patterns. When the light from the beam reaches a distant photodetector, the electronic waveforms that are produced can be amplified to reproduce the original sounds.

The Metrologic Speed of Light/Laser Video Kit contains an appropriate photodetector, amplifier and speaker for this particular application.



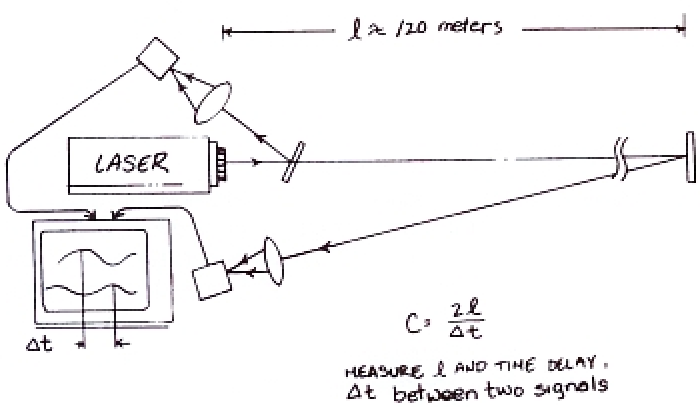
55. Modulation, Video Transmission

Connect the output of a TV camera or video recorder to the video jack at the back of a modulated laser. The video signals will vary the intensity of the laser beam. Set up a distant video receiver (wide-bandwidth phototransistor and video amplifier) to receive the modulated laser beam and operate a black and white or a color TV monitor to produce the images. Full resolution cannot be attained using a helium-neon laser because its bandwidth (about 0.6 MHz) is smaller than that of a TV signal (4.2 MHz). However, a solid-state VLD laser is more than adequate for the purpose.



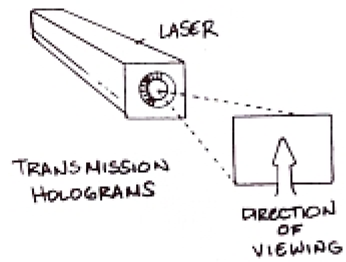
56. Speed of Light, Modulation Method

Use a modulated laser to measure the speed of light across a football field and back. Set up a distant mirror at the far end of the field and partially insert a small mirror into the beam path near the laser to isolate a small percentage of the light. Direct the reflected light from each mirror into a separate photodetector placed near the laser. If the photodetectors are connected to an oscilloscope and an rf signal generator is used to modulate the laser, the resultant of two waveforms will be displayed on the oscilloscope screen. Because of the time delay to send the light over the long leg, the two photodetector inputs will be slightly out of phase. The phase difference between the two waveforms can be measured and equated to the difference in travel time of the two beams. The speed of light can be calculated using this time and the distance.



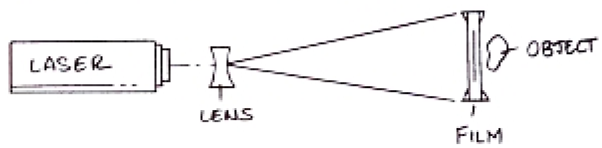
57. Holography, Observing Holograms

In a darkened room, expand a laser beam with a diverging lens. Hold a hologram in the laser beam path and allow the laser light to enter your eyes. Search for the holographic image within an angle of 20 to 40 degrees to the right or left of the laser but DO NOT stare directly into the laser.



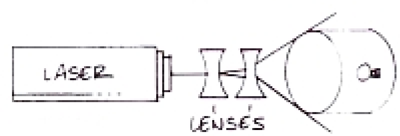
58. Holography, Making White Light Reflection Holograms

Cut a small piece of non-AH (anti-halo) holographic film into a two-inch square. Place the film between two pieces of glass. Hold the glass together using two ordinary binder clips. Use a diverging lens to expand a laser beam. Direct the beam through the film onto an object placed directly behind the film. The hologram is formed between the reference beam coming from the laser, and the object beam, coming form the object. Reflection holograms can be viewed in white light (See Metrologic's book *Holography Using a Helium-Neon Laser* written by Dr. Tung Jeong for details).



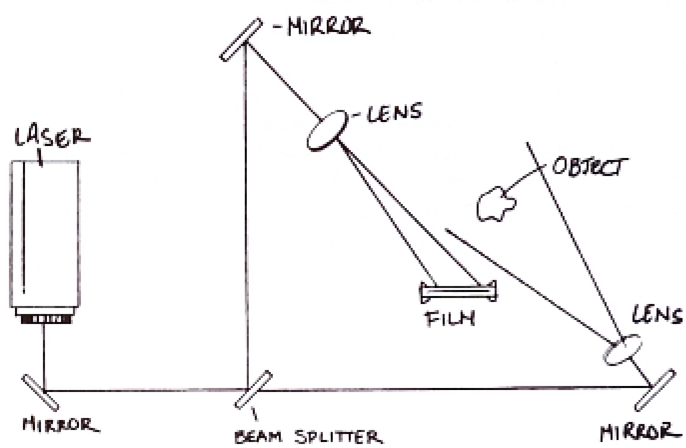
59. Holography, Cylindrical Holograms

A 360-degree view of an image can be obtained by strapping a hologram inside a glass cylinder, emulsion side inward. Wrap a piece of film, emulsion side inward, inside a cylinder. Use a diverging lens to expand a laser beam. Shine the beam into the top of the cylinder and observe the image through the glass sides.



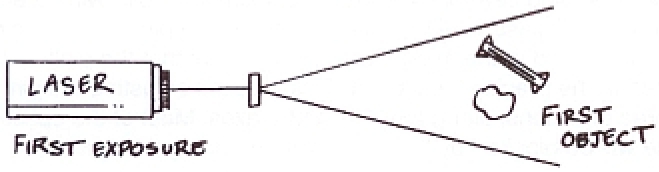
60. Holography, Transmission Holograms

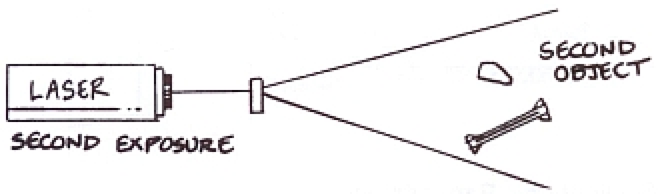
The best depth of field and sense of perspective is obtained with transmission holograms. A recommended setup to make one requires the splitting of a laser beam. Allow one beam to go directly to the film. Direct the second beam at the object, and then to the film. This type of hologram can only be seen using laser light.



61. Holography, Multiple Channel

More than one picture can be stored on holographic film. A simple method is to make the first exposure, then change the angle of the film plate and make a second exposure using a second object. Two separate pictures can be seen by tilting the film plate. (See *Holography Using a Helium-Neon Laser* for further details.)



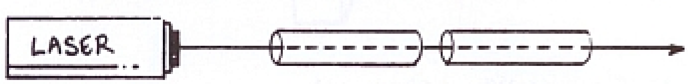


62. Holography, Holographic Interferometry

Holography is widely used in industry to observe minute changes in materials. The technique involves making two exposures of the same object; between exposures, the object is moved or changed. The resulting hologram shows the object covered by light and dark interference fringes, which indicate a 1/4 wavelength change. For example, shoot a C-clamp, tighten it slightly, and shoot again. Interference fringes will show where the clamp is under the greatest stress (See *Holography Using a Helium-Neon Laser*, by Dr. Tung Jeong).

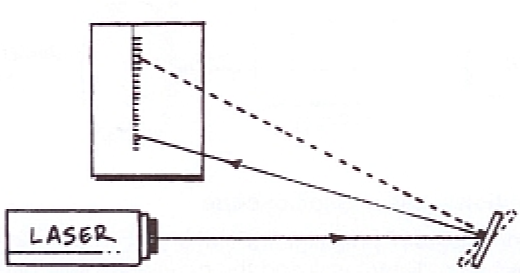
63. Applications, Pipe Laying

Most major sewer and storm drain pipe installations are aligned using helium-neon lasers. A laser beam is aimed down the center of a pipe. As each successive pipe is connected, a round disc with a center hole is placed over the end of the pipe. The pipe is moved slightly until the laser beam shines through the central hole. This provides fast and accurate alignment and cost-efficient drainage.



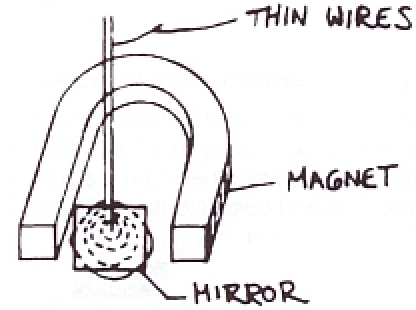
64. Applications, Optical Lever

Attach a mirror to an object. Aim a laser beam at the mirror and allow the reflected beam to fall on a distant screen. Any small movements or changes in the object will cause a large displacement of the red dot on the viewing screen.



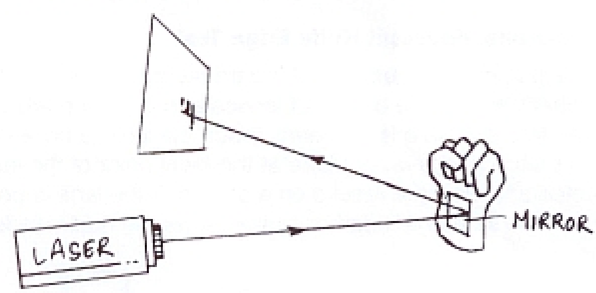
65. Applications, Optical Galvanometer

Wind 20 turns of insulated wire around a screwdriver handle. Remove the screwdriver and tape the coils together. Attach two thin strands of wire to the ends of the coil. Using a small piece of cellulose or double-face tape, fasten the coil to a thin mirror. Suspend the coil and mirror between the poles of a horseshoe magnet. Aim a laser at the mirror and observe its reflection on a distant wall. Do not stare at the laser beam or its bright reflection. Apply a small current to the coil and the mirror will twist, resulting in a laser beam deflection. Using the appropriate shunts and multipliers, calibrate the galvanometer to read amperes and volts. An ammeter or voltmeter may be used for comparison.



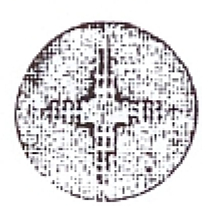
66. Applications, Pulse Indicator

Use adhesive tape to fasten a small mirror to your wrist directly over the point where the pulse is found. Aim a laser at the mirror and observe its reflection on a wall. Even when holding your wrist steady on a table, small movements in the mirror due to your pulse will be observed as large deflections on the wall.



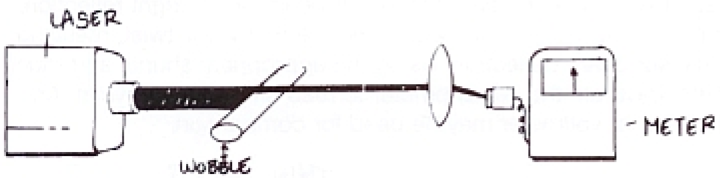
67. Applications, Laser Art

Many laser lighting effects are created by sending laser light through transparent materials, such as reticulated plastics that are used as diffusers in fluorescent ceiling lights. The fine mesh cloth used in silk screen printing produces interesting symmetrical arrangements of dots of light. Low cost diffraction grating can be used to split the beam into dots arranged in a single straight line. For slowly changing patterns, aim the laser beam through transparent liquids, such as oil and water in a shallow glass container.



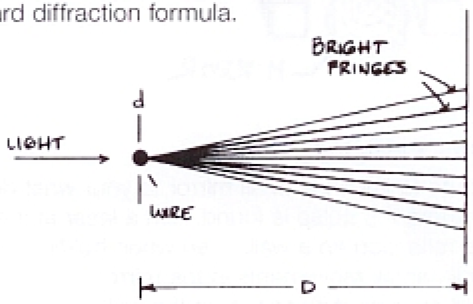
68. Applications, Inspecting Wobble or Height

Expand a laser beam to a diameter larger than the anticipated change in wobble or height. Direct the laser beam across the edge of an object, and then into a lens that will focus the beam to the photocell of a laser power meter. The power at the detector will vary depending on how much of the beam is obstructed by movement of the object.



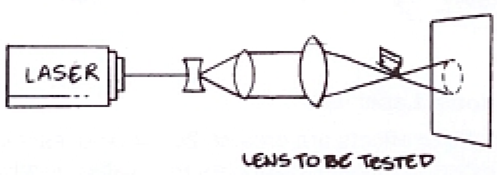
69. Applications, Measurement, Wire Diameter

Laser light diffraction is being used in industry to measure the thickness of fine wire. Direct a laser beam at a filament, such as a human hair. Measure the spacing between the light and dark areas of the diffraction pattern and calculate the diameter of the hair using the standard diffraction formula.



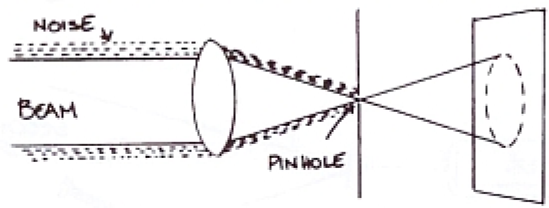
70. Applications, Foucault Knife Edge Test

The Foucault knife edge test is a standard technique used in the optics industry to test the quality of lenses and curved mirrors. Use two lenses to collimate a laser beam. Place the lens to be tested in the beam path. Insert a razor blade at the focal point of the lens being tested and view the results on a screen. If the lens is perfect, the spot on the screen will darken uniformly as the razor blade cuts the beam.



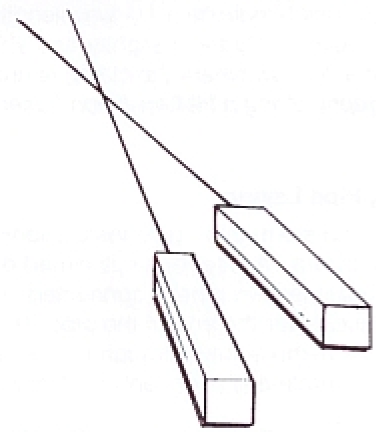
71. Applications, Spatial Filter

A spatial filter cleans a laser beam by removing optical noise. Direct a laser beam at a converging lens, and then center a pinhole at the apex of the cone of light produced by the lens. The pinhole should be large enough to let the primary beam pass through easily, but small enough to block any stray light. (Suitable pinholes can be made by folding several thicknesses of aluminum foil, laying them on a piece of glass, and puncturing them with a pin. The best pinholes are found in the middle folds.) It is critical that the pinhole be placed at the precise focal point. This requires adjusting the pinhole in three directions, along the X, Y, and Z axes. Most of the optical noise will be blocked by the material surrounding the pinhole.



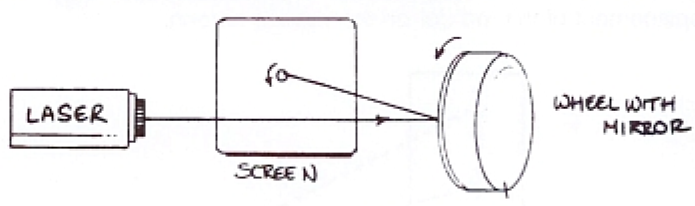
72. Applications, Rangefinding

Use two lasers (or use only one laser with a beam splitter and a mirror) to generate two laser beams that are separated by at least 50 cm. Leave one of the lasers fixed, and rotate the other laser so that the beams intersect on distant objects. Use triangulation trigonometry or a tape measure to calibrate the rotation angles that are required to target objects in terms of their distances from the lasers.



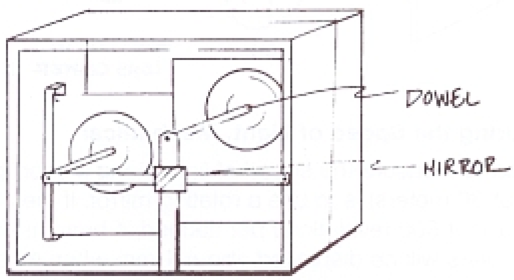
73. Applications, Wheel Alignment

Mount a mirror in the center of a wheel so its surface is perpendicular to a laser beam. Rotate the wheel and observe the reflected light on a distant wall. If the wheel or shaft is out of alignment, the reflected light forms a circle. If the wheel or shaft is properly alighned, the reflected light comes to a point.



74. Applications, Laser Oscilloscope

Using the principles of optical amplification, Lissajous patterns can be projected on a distant wall and the principles of an oscilloscope can be demonstrated. Mount two 3-inch radio speakers in a frame as shown in the diagram. Glue one end of a short wooden dowel to the center of each speaker. Glue the other end of the dowel to a thin strip cut from a plastic ruler; attach the free ends of the plastic strips to the frame. Cement a small mirror over the area where the plastic strips intersect. Aim the laser at the mirror and observe its reflection on a distant wall. Do not stare directly at the beam or its bright reflection. Connect an audio oscillator to speaker 1 and another to speaker 2. Adjust the oscillator frequencies to produce a variety of large Lissajous patterns on the wall. Horizontal deflections of the beam are produced by speaker 1. Vertical deflections of the beam are produced by speaker 2.

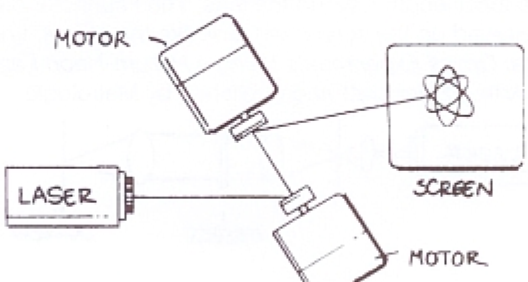


75. Applications, Detect Flaws

Shine a laser beam on a surface to detect flaws and scratches in a material. Scattering of the light will occur where a flaw or scratch is present.

76. Applications, Lissajous Patterns

Among the most well-known laser lighting effects are Lissajous figures, a swirling pattern of interwoven circles which have become almost a trademark of laser light shows. These intricate patterns can be created easily. Mount small mirrors on the rotor shafts of two variable speed motors. Position each mirror at a slight angle so that when the shaft rotates, a small circle is reflected. Place the laser and the two motor/mirror assemblies so that the laser beam follows a Z-shaped path, from the laser to one mirror, to the second mirror, and then to a wall or screen. If the speed of each motor can be adjusted independently, a great variety of Lissajous patterns can be created.

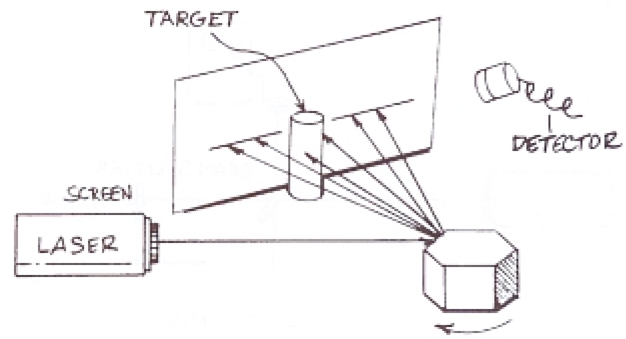


77. Applications, Wave Guides

A look into the future shows small, solid state lasers producing on optical signal which will be carried miles by a fiber optics wave guide. Low loss wave guides will be a necessity to produce an effective laser communication system. To make a low loss wave guide, fill some quartz tubing with purified trichloethylene. Losses less that 20 dB/km have been reported using this liquid core wave guide, although losses of more than 1.2000 dB/km are usually found with conventional glass fibers. Try making your own wave guides and measure the losses with the aid of a laser power meter.

78. Applications, Measurement by Scanning

Mount a mirror or a many-sided prism on a motor that rotates at a constant speed. Direct the laser at the mirror and place a photodetector in the reflected beam. As the motor rotates the mirror at a known rate, the reflected beam scans the target and its width can be measured by the time that the detector is activated. Laser bar code scanners measure the widths of the bars on bar code symbols to the thousandth of an inch.

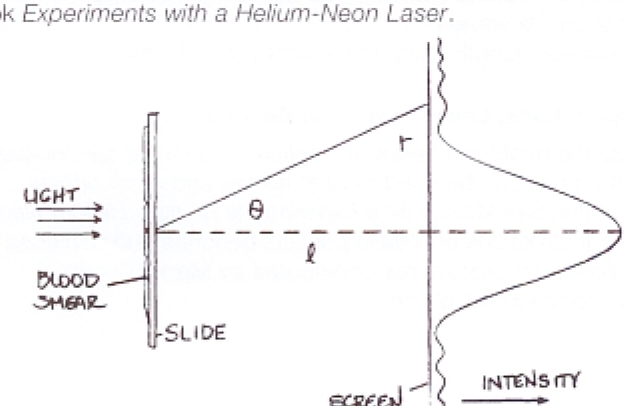


79. Applications, Opthalmology

When an enlarged laser beam is aimed at a wall, the illuminated area appears to have small spots or grains. This granular appearance is caused by a complex interference pattern produced by the coherent light as the lens of our eye focuses it on the retina. Expand a laser beam with a lens and project it on a wall or screen. Move your head slowly from side to side while observing the spot. If you are farsighted or your eyesight is normal, the spots will move in the same direction as your head. If you are nearsighted, the spots will appear to move in a direction opposite from that of your head. In nearsighted persons, the eye tends to focus the pattern a short distance in front of the retina. Therefore, parallax caused by the head movement results in an apparent motion of the spots in the opposite direction.

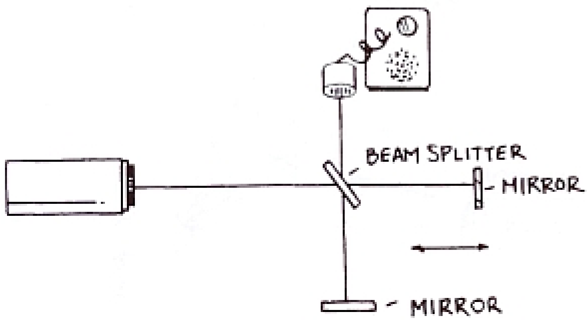
80. Application, Measure Blood Cell Diameter

Use the Airy disc principle in No. 42 to measure the diameter of a blood cell. Place a drop of blood on a clean microscope slide. Gently spread the sample across the slide using the edge of a second slide, being careful not to crush the red blood cells or destroy their circular symmetry. Place the slide within a laser beam, then move the slide around until a good set of diffraction rings is observed on a screen. Measure the distance from the cells to screen and the diameter of the first fringe. Calculate the diameter of the blood cell using the technique reported by Dr. James E. Parks of Western Kentucky University. Details can be found in Metrologic's book *Experiments with a Helium-Neon Laser*.



81. Applications, Doppler Effect

The Doppler effect is a well-known phenomenon by which wave frequency is changed by a moving object. Use a Michelson interferometer setup. Superimpose the two reflected beams on a Speed of Light Kit. Move one of the front surface mirrors back and forth slowly. This will produce an audible tone from the loud speaker because the wavelength of light is changed. Rapid movements, however, produce frequency changes that are supersonic and cannot be heard.



82. Applications, Calibrating a Diffraction Grating

Shrinking or expansion of the film or other diffraction grating media can change the line spacing of a diffraction grating. Always check the calibration of a new diffraction grating with the aid of a helium-neon laser as follows:

1. Align the beam of a helium-neon laser so it turns right angles with the surface of a distant screen.
2. Tape the diffraction grating over the laser aperture. Observe the central maximum spot and spots from other orders that appear on the screen.
3. Calculate d (the distance between diffraction grating lines) using the equation $\lambda = d \sin \theta$.
   where: λ is 633 X 10^{-9} meter and
   θ is the angle between the central maximum and the first order maximum

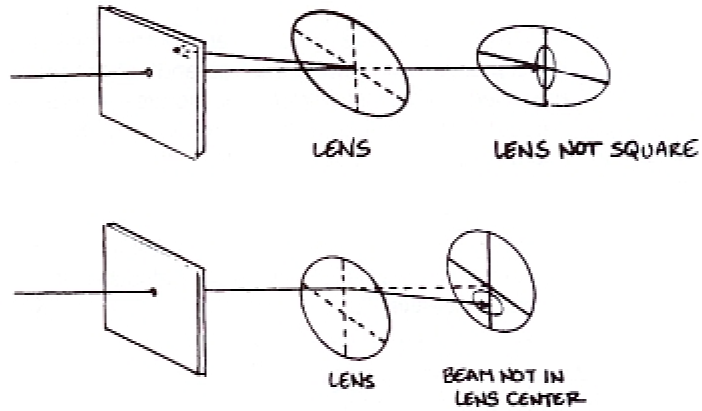
83. Applications, Measuring Wavelength of a VLD Laser

The wavelength of a VLD laser can be anywhere from 660 to 680 nm depending on the geometry and temperature of the individual laser chip. To find its precise wavelength:

1. Calibrate a diffraction grating using the procedure given in the item above.
2. Align the beam of the VLD laser so it forms right angles with the surface of a distant screen.
2. Tape the calibrated diffraction grating over the laser aperture. Observe the central maximum spot and the first order spots that appear on the screen.
3. Find the wavelength using the equation $\lambda = d \sin\theta$

84. Applications, Leveling Optical Benches

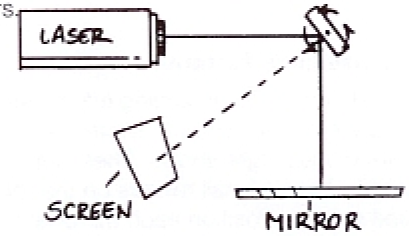
Because the bright red beam of a helium-neon laser can indicate the light path, it can be used to align lenses and other optical components. See Metrologic's *Experiments Using a Helium-Neon Laser* for instructions on leveling optical benches and centering lenses based on procedures contributed by Martin Dvorin of Monroe Community College.



85. Measuring the Speed of Light, Mechanical

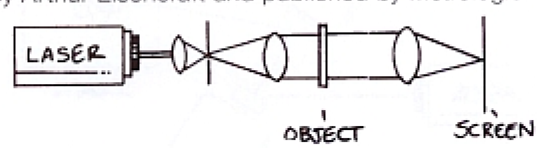
One method to measure the speed of light along a short path of travel (about 30 meters) is to use a rotating mirror. If the mirror is rotating at about 500 revolutions per second, a beam traveling about 40 meters will be displaced about 4 mm when measured on a screen. Use lenses in the optical system to focus the laser beam on a viewing screen for precise measurements.

Details can be found in Metrologic's *Experiments Using a Helium-Neon Laser*. Dick Pontine, of Hamline University, reports measurements having less than 3% error using various distances from 20 to 60 meters.



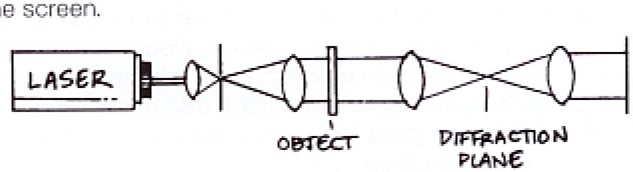
86. Physical Optics, Fraunhofer Diffraction

Form a collimated laser beam about 1 inch in diameter. Place transparencies of test patterns within this beam. Place a converging lens one focal length beyond the transparency and and a viewing screen one focal length beyond the lens. The Faunhofer diffraction pattern observed on the screen will look like the object. For details see *Physical Optics Experiments Using a Helium-Neon Laser* written by Arthur Eisencraft and published by Metrologic



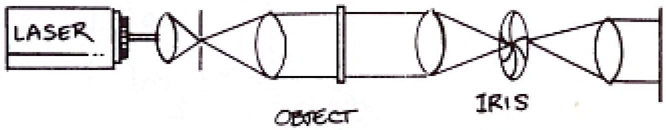
87. Physical Optics, Filtering Fraunhofer Diffraction Patterns

Follow instructions in No. 84, except remove the screen. The focal point where the screen was located is the diffraction plane. Beyond the diffraction plane, add another lens to collimate the light and to project it to a screen. Place various masks or filters at the diffraction plane and observe the portions of the patterns that are transmitted to the screen.



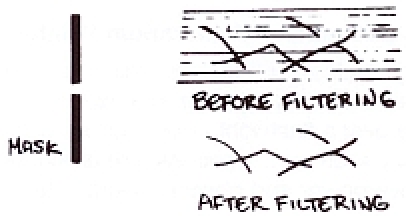
88. Physical Optics, Spatial Frequency

Place a variable diameter iris at the diffraction plane described in No. 85. An increase in the size of the iris permits more of the diffraction pattern to contribute to the image. Experiment with various object transparencies and discover that widely spaced lines are encoded near the center of the iris, while tightly spaced lines are encoded far from the center. As the iris is opened, higher spatial frequencies are transmitted, adding detail to the image.



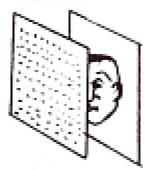
89. Physical Optics, Image Noise Suppression

Follow the instructions in No. 84. A mask similar to the one illustrated here will help suppress horizontal information.



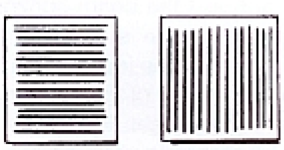
90. Physical Optics, Image Enhancement

Follow the instructions in No. 84. A continuous tone, photographic image can be recovered from a halftone dotted image by placing a small aperture at the diffraction plane.



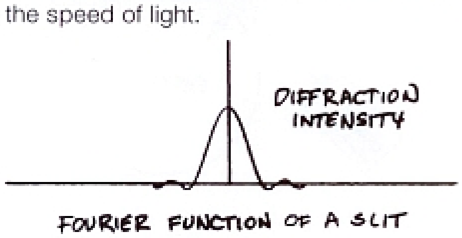
91. Physical Optics, Multiple Channel Information Storage

Photograph a picture or image modulated by horizontal lines. Expose it again with an image modulated by vertical lines. The double exposure now stores two images. Either of the images can be retrieved by viewing the composite using the appropriate mask at the diffraction plane.



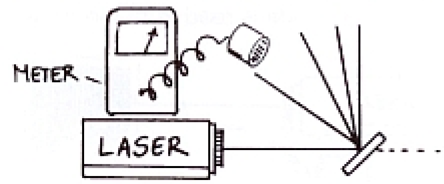
92. Physical Optics, Fourier Transforms

The diffraction patterns observed using Metrologic's Physical Optics lab are examples of Fourier analysis of the slit or other functions. The masks in the lab compute and display the Fourier transform at the speed of light.



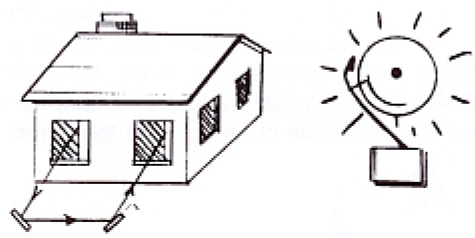
93. Polarization, Angle of Beam Splitter

Place a glass microscope slide in the laser beam at an angle so that the beam will be reflected 10 degrees from normal. Observe variations in the intensity of the transmitted and reflected beam over a 1 to 2 minute period. Repeat by rotating the slide in 10 degree steps until the slide has been rotated 90 degrees. At what angles are the fluctuations in intensity prominent? Are these angles related to Brewster's angle? The fluctuations occur because the beam splitter serves as a polarizer at certain angles. Beam splitters reflecting at small angles, such as 10 and 20 degrees, will not serve as polarizers. This experiment is best performed while the laser is warming up. After the warm-up period the laser's polarization takes longer to change.



94. Practical Applications, Burglar Alarm

A laser may be aimed through a window to the outdoors and then reflected as desired by a series of mirrors to form an invisible fence that ends in a photodetector. Whenever the beam is broken the detector signal operates any conventional burglar alarm siren or communication device.

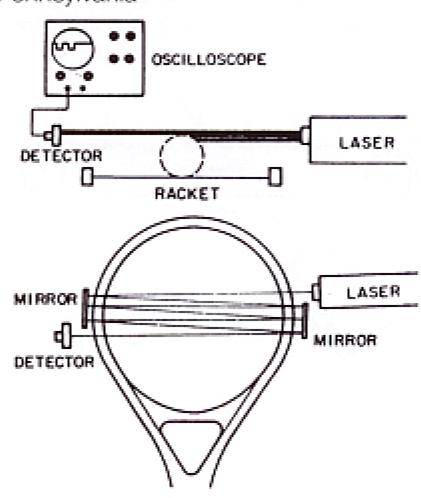


95. Practical Application, Tennis Racket Performance

Secure a tennis racket to a table using a heavy vise or C-clamp. Place a ball on the racket and aim a laser beam so it just grazes the top of the ball as shown in the diagram. A photodector connected to an oscilloscope produces a trace which can show the initial velocity, ballstring contact time, and the rebound velocity.

For further information, see "Physics of the Tennis Racket" in the June 1979 issue of the American Journal of Physics.

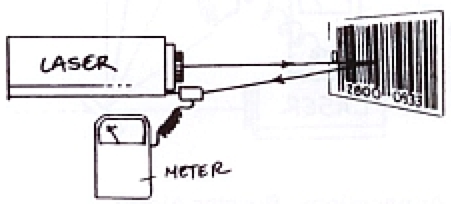
Contributed by Howard Brody, University of Pennsylvania, Philadelphia, Pennsylvania



96. Practical Application, Bar Code Reading

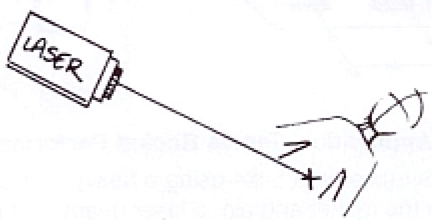
Bar code data on grocery products can be decoded because the bar code reflects laser light in a distinctive pattern from the contrasting bars and spaces. The reflected light is received by a photodetector and the signals are converted into digital data that can be processed by a computer.

The Universal Products Code (UPC) shown on the diagram below starts with four long bars to initiate the reading sequence, the number 2800 which is the manufacturer's identification, 0933 which is the number of the product, and four long bars to end the sequence. The long bars at the beginning and end differ slightly in their width and spacing. This tells the computer to make an automatic correction if the bar code is read from the reverse direction.



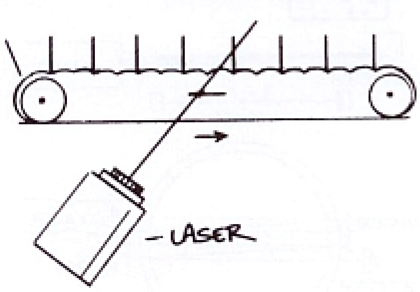
97. Practical Applications, Targetting

A narrow, collimated laser beam can pinpoint targets and help align apparatus in a very short time. One classic example is the "Monkey and Hunter" demonstration. A laser is aimed through a blowpipe gun at a monkey target suspended from the ceiling. After the alignment, the "Hunter" operates the blowpipe, sending a missile towards the target. At the same instant an electromagnet releases the monkey. Since both the missile and the monkey fall with the same acceleration, the missile does not miss the target.



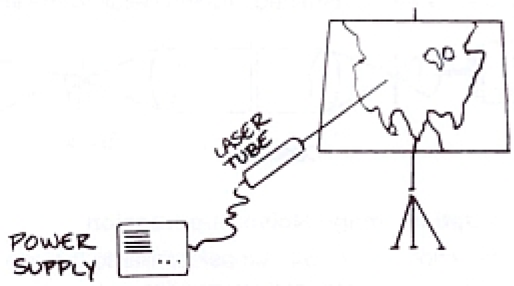
98. Practical Applications, Counting

Everything from freeway traffic to items on a conveyor line can be counted as they break a laser beam set up between a laser and a photodetector. An electronic calculator can be modified to record a count each time the beam is broken. This technique can also be used with ordinary light, but the laser is preferred because its narrow beam does not require focusing and red filter minimizes interference from ambient white light sources.



99. Practical Applications, Laser Pointer

Use the red laser beam as a pointer for slide shows or lectures in which you want to call attention to areas on maps, charts, or photographs. The laser produces a small bright spot that can be clearly seen on a brightly illuminated projection screen. Furthermore, the beam does not have to be refocused each time the distance from the lecturer to the screen changes.

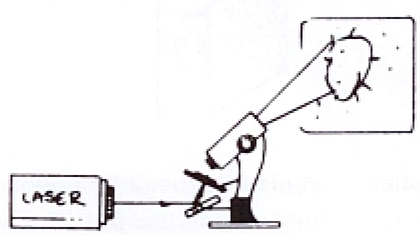


100. Practical Applications, Planetarium Pointer

Use the Metrologic VLD laser ML268 to point out stars, constellations and other features that are projected on a planetarium dome. Its major advantage over a flashlight arrow pointer is that the narrow red beam is easily seen on the planetarium dome, but its brightness does not overpower and obscure nearby stars.

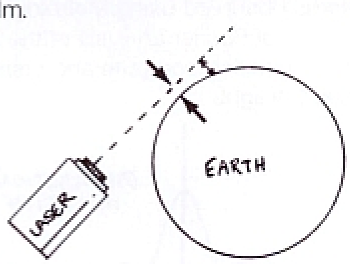
101. Practical Applications, Microprojector

Shine the laser at the substage mirror and remove the eyepiece of a microscope to use it as a microprojector. A screen placed at the focal plane of the objective lens will produce an enlarged image of the specimen on the stage so it can be viewed by several people simultaneously.



102. Practical Applications, Measuring the Curvature of the Earth

Set the laser on a tripod a short distance above the ice on a large frozen lake. Collimate and aim the beam horizontally over the ice with the aid of an accurate bubble level. Several kilometers away set up a telescope to intercept the laser beam. Because of the curvature of the earth, the height of the telescope above the ice will be greater than that of the laser. By measuring the distance over the ice (see No. 72) and by measuring the difference in height between the laser and the telescope, the size of the earth can be calculated. If there is no ice, try it using boats on a day when the water is mirror calm.



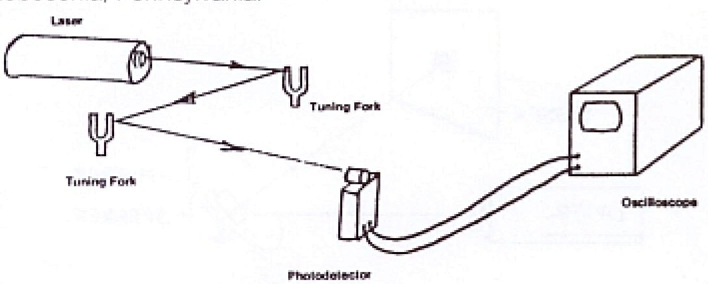
103. Practical Applications, Artificial Rabbit

This last application is a bit frivolous but it usually works and might possibly be useful to someone. On a dull day or after the sun has set, aim your laser out the window so it makes a small spot on the grass or bushes outside. If the beam is moved about, most dogs will run as fast as they can trying to catch the spot.

104. Demonstration, Laser Beats

To visualize the phenomena of beats and intensify the sound for a large audience, use the setup shown in the diagram below. The tuning forks have polished prongs and are mounted on resonance boxes. Adjust the frequencies of the tuning forks with sliding weights so the difference is 10 Hz or less. The reflected beam can be displayed on a screen, generate waveforms on an oscilloscope, or can be detected and amplified to be heard in a large lecture room.

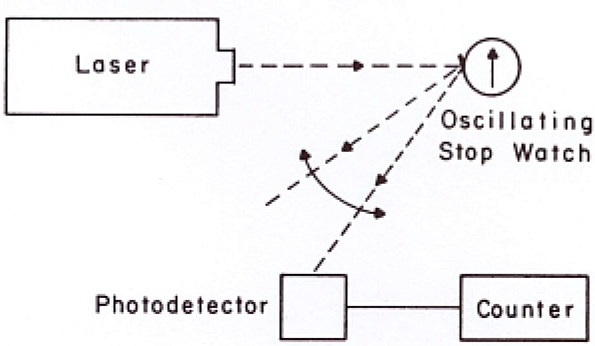
Contributed by Ellis D. Noll, Conrad Weisner High School, Robesonia, Pennsylvania.



105. Demonstration, Conservation of Angular Momentum

Glue a tiny mirror chip to the side of a stopwatch. Balance the stopwatch on top of an inverted watch glass placed on the table. Aim a laser beam at the stopwatch mirror so its reflection produces a small spot on a screen about 2 meters away. When the watch is running, a streak of light is seen on the screen. Its length is proportional to the angular displacement of the watch. It is also possible to compute the frequency of oscillation (5 Hz), the period, the angular velocity, and the angular momentum using the setup shown below.

Contributed by Arthur R. Quinton, University of Massachusetts, Boston, Massachusetts.



FUN IDEAS USING A LASER

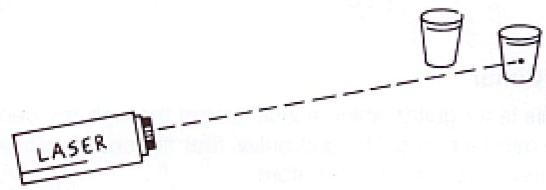
By Herbert H. Gottlieb, Physics Teacher

The ideas presented here are guaranteed to have little or no educational value. But they might provide some lighthearted entertainment and possibly motivate student interest in the more serious topics that are scheduled for the day's lesson.

1. Laser Disintegrator

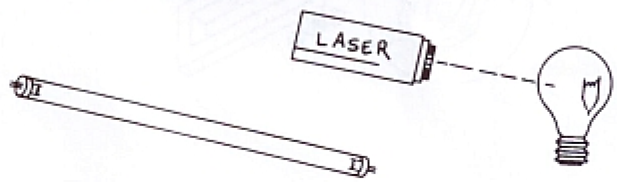
Set two styrofoam coffee cups on the lecture table and pour about 50 ml of water into each. Expose one of the cups to a laser beam for exactly five seconds and then invert both cups. Water will spill out of the unexposed cup as expected but nothing comes out of the other cup. Apparently, water is disintegrated by laser electrolysis.

(If difficulty is experienced when practicing this demonstration, put a dry sponge into one of the cups and try again.)



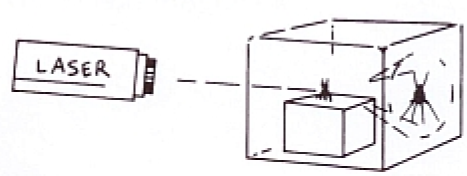
2. Laser X-Ray

Aim a laser beam so it strikes the side of a frosted incandescent lamp bulb. An "X-ray" of the lamp filament and its supporting wires will appear on the opposite side of the bulb. It is easy to tell whether or not the filament is broken. Using this technique, it is also possible to make a detailed examination of the filaments hidden inside each end of a fluorescent lamp.



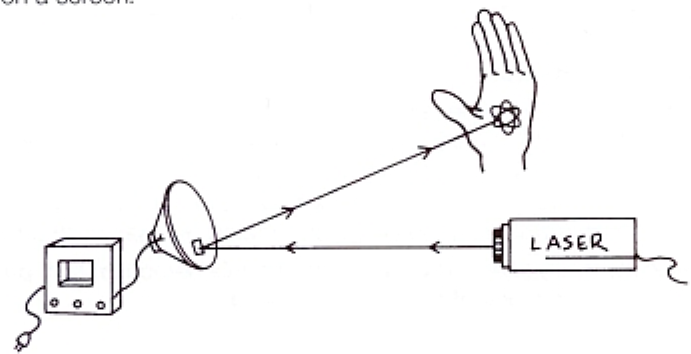
3. Monster Movies

Place a small bug on a platform inside an inverted food container made of frosted plastic. Aim a laser so it illuminates the bug through the container. A projection of the bug will not only appear on the far side of the container, but the shadow will keep changing in size as the bug moves around inside.



4. Grasping a Laser Image

Stick a small mirror to the cone of a speaker that is connected to either an audio oscillator or the earphone jack of a tape recorder. With the apparatus playing, aim a laser beam at the mirror and catch its reflection on the palm of your hand instead of projecting it on a screen.

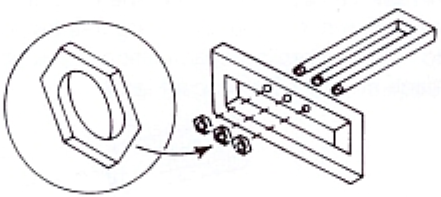


5. Laser Guitar

To play this laser guitar, shine a laser beam through the center and pluck the middle prong. We guarantee that the sound will be unlike any that you have ever heard before.

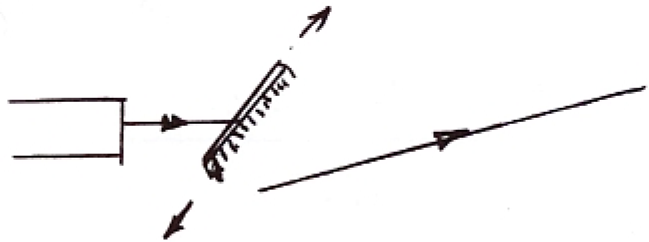
Assembly is easy but it might be difficult to find all of the parts in your local hardware store…especially the three nuts that secure the prongs to the mobius frame.

Perhaps you can entice some students to build one for the local science fair.



6. Laser Beam Saw

Aim a laser beam at a solar cell that is connected to the micro-phone jack of an audio amplifier. Run the teeth of a pocket comb through the laser beam and listen to the sound produced. If the motion of the comb is rapid, a sound familiar to that of sawing wood is produced. Try cutting the laser beam in two places about 15 cm apart. Then pick up the sawed laser beam from the table (a red soda straw) and pass it around the room for everyone to admire.



7. Laser Light Show

Tape a small, lightweight mirror to a speaker cone that is connected to the output of a radio or tape deck. Shine a laser beam at the mirror, reflecting it onto a wall. The beam will dance around on the wall in a pattern set by the music.

Lightweight, front-surface mirrors are included in the Metrologic "Laser Optics Lab".