Modern Laser Optics Kit

Instruction Guide

Model Number:

IF 535

INDUSTRIAL FIBER OPTICS

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Revision C

Printed in the United States of America

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The procedures in this manual are written for use with Industrial Fiber Optics helium neon and diode lasers. You may need to adjust the steps slightly to accommodate other manufacturers' lasers.

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LASER CLASSIFICATIONS

All manufacturers of lasers used in the United States must conform to regulations administered by the Center for Devices and Radiological Health (CDRH), a branch of the U.S. Department of Health and Human Services. CDRH categorizes lasers as follows:

Class	Description
I	A laser or laser system which does not present a hazard to skin or eyes for any wavelength or exposure time. Exposure varies with wavelength. For ultraviolet, 2 to 4 μm exposures is less than from 8 nW to 8 μW. Visible light exposure varies from 4 μW to 200 μW, and for near-IR, the exposure is < 200 μW. Consult CDRH regulations for specific information.
II	Any visible laser with an output less than 1 mW of power. Warning label requirements — yellow caution label stating maximum output of 1 mW. Generally used as classroom lab lasers, supermarket scanners and laser pointers
IIIa	Any visible laser with an output over 1 mW of power with a maximum output of 5 mW of power. Warning label requirements — red danger label stating maximum output of 5 mW. Also used as classroom lab lasers, in holography, laser pointers, leveling instruments, measuring devices and alignment equipment.
IIIb	Any laser with an output over 5 mW of power with a maximum output of 500 mW of power and all invisible lasers with an output up to 400 mW. Warning label requirements — red danger label stating maximum output. These lasers also require a key switch for operation and a 3.5-second delay when the laser is turned on. Used in many of the same applications as the Class IIIa when more power is required.
IV	Any laser with an output over 500 mW of power. Warning label requirements — red danger label stating maximum output. These lasers are primarily used in industrial applications such as tooling, machining, cutting and welding. Most medical laser applications also require these high-powered lasers.

INTRODUCTION

Welcome to the exciting world of modern optics. The kit you are going to use contains a variety of optical elements. These elements will allow you to begin to explore the many aspects of modern optical technology. All of the optics mounts are easy to use and from each you will learn about another aspect of modern optic technology. All you must provide is the laser.

This manual is an instruction guide and technical reference for Industrial Fiber Optics' Modern Laser Optic Kit. The manual contains step-by-step instructions to guide you in setting up the laser and use of each optical element. Each optical mount is also discussed in detail, including visual effects, how the optical element created a particular effect and practical real-world applications. With the nine optical mounts found in this kit you will experiment with geometric and diffraction optics, polarization and one of the latest developing optical technologies — fiber optics. At the end of the manual are four reference sections to help explain individual optical technologies.

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 Internet.

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

Sincerely,

The Industrial Fiber Optics Team

EQUIPMENT NEEDED

- Modern Laser Optics Kit.
- Helium neon or diode laser producing a visible light emission with a 3/4 inch × 32–thread optical mount (found on most low-powered educational lasers.)
- Wall or other flat vertical surface.

* Any laser which produces visible light is suitable for use with this optics kit. This includes helium neon and diode lasers. The displays produced by diode lasers for the turquoise and blue optic mounts will not be quite as sharp as those created by a helium neon laser, but will be entirely adequate.

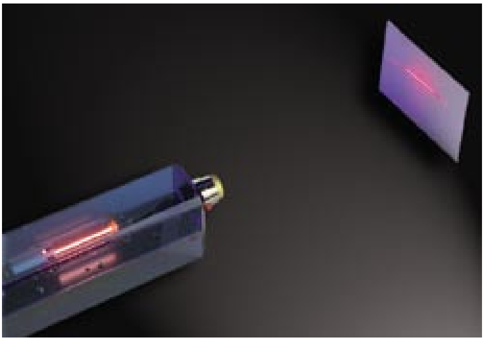
Kit Components

Your optics kit contains this manual, a length of clear optical fiber and the following colored, threaded optics mounts:

Violet
Turquoise
Green
Bronze
Blue
Red
Silver
Black
Gold

SETUP

1. Review the laser safety rules on the back cover of this manual.
2. Find a table approximately 600 × 900 cm (2 × 3 feet) or larger in size from which the laser can be pointed to a vertical wall or dull reflecting surface. The distance from the laser to the surface should be approximately three meters (10 feet).
3. Push the laser beam stop handle downward to its closed position and make sure its ON/OFF switch (SW) is in the OFF position. (The push button should be in its extended position.)
4. Plug the 110 VAC-to-DC power adapter (provided with the laser) into an AC wall outlet. Insert the cord from the power adapter into the power jack (PWR) located on the rear of the laser.
5. Depress the ON/OFF switch (SW) on the control panel of the laser until it clicks into the ON position. (The switch should be slightly depressed.) The pilot light (green LED) just to right of the ON/OFF switch should now be lit, showing that the laser is on.
6. Push the laser's beam stop handle upward, to its open position.
7. Observe the red beam striking the wall, or other surface, in the direction that the laser is pointed. Keep the laser pointed in this direction during all experiments.
8. Push the laser's beam stop handle downward, to its closed position.
9. The next section contains descriptions of each of the nine optic mounts. We suggest that you install the optic mounts and observe the resulting laser beam patterns in the order they are listed in the section titled "Optics Mounts."
10. You will gently thread the colored optic mounts in your kit into the laser's optics mount. Note: Make sure the beam stop handle is in the downward or closed position when attaching and removing each threaded optic mount.
11. Dim the room lights and observe the unique pattern on the wall that each of the optic mounts produces. Note: Each threaded mount may need a slight turning adjustment to produce optimum visual patterns.



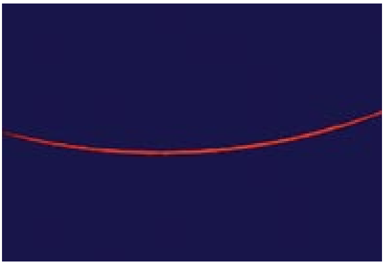
12. Turn on the room lights, then push the beam stop handle on the laser down to its closed position. Remove the threaded optic mount and place it back in the optics kit. Continue with the next optic mount using the same procedure, starting with steps 10 and 11.
13. When you have finished experimenting with the optics mounts, turn off the laser, disconnect its power cord at both ends and put away all the materials used in this experiment.

OPTICS MOUNTS

Broad Beam (violet)

This optic mount, when installed in a laser, positions a cylindrical rod or lens in the path of the laser beam. The laser beam passing through the cylindrical lens will be spread in one (dimensional) plane to produce a broad line, as shown in the picture to the right. Screw the violet optic mount into the laser and observe the resulting laser pattern. Rotate the threaded optical mount and observe the rotation of the laser line. Notice that the cylindrical lens in the mount is at a right angle to the line on the wall. One application of using a laser and lens in this fashion is aligning items according to similar heights or positions.

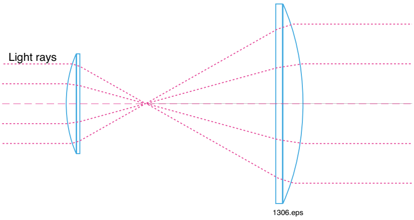
Arc Beam (bronze)



This optic mount is similar to the previous mount except the cylindrical rod has been placed at a complex angle to the laser's light beam instead of being at a right angle. This complex angle causes the laser beam to intercept the rod at a continuously varying angle, which will produce an interesting visual result. Attach the bronze optical mount and observe the resulting pattern for yourself.

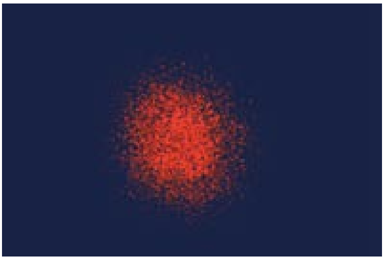
The pattern you should see with this optic mount is an arc or segment of a circle. Rotate the mount and observe the different visual effects, with the position of the laser beam changing in response to the changing position of the lens.

Diverging (red)



In some applications it is desirable to have a laser beam diameter larger than the 1-to-2 mm beam size typical of the laser you are now using. One application requiring a larger light beam is the exposure of holographic film, where we would want to illuminate an entire object, rather than just a small portion of that object. One way to increase the size of a laser beam is shown by the optics configuration to the right. The pair of optical lenses used in this manner is commonly called a "beam expander."

Screw the diverging (red) optic mount into the laser. Observe the large dispersed beam on the wall or screen. The diverging laser beam in this optic mount was created with a short length of special glass rod. The rod intercepts the laser beam and breaks it into many small diverging beams.



This seemingly simple pattern on the wall can be used to test your eyes! Look directly at the spot on the wall where the laser beam strikes until you see a speckled light pattern consisting of many small dots. You may have to look carefully to see the tiny dots. Move your head very slowly from side to side while observing the spot. If you are "farsighted" or if your eyes are normal, the small spots will appear to move in the same direction as your head. If you are "nearsighted," the spots will appear to move in a direction opposite that of your head movement.

Another experiment you can perform is to observe the effects of evaporation. Place a small amount of isopropyl (rubbing) alcohol on the end of the glass rod with a cotton swab. When the alcohol evaporates you will see the laser spot move.

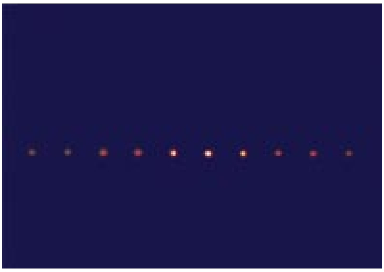
Double-slit (turquoise)

The optical mounts you have used so far have had geometric optical elements to focus or change the direction of the laser beam. (See page 9 for a more detailed explanation of geometric optic principles.) Another technique that scientists and engineers often use to create special effects or manipulate light is diffraction. To learn more about diffraction let's begin by passing the laser beam through two narrow slots.

Attach the turquoise optic mount to the laser by following the procedures previously described and observe the pattern. The laser light pattern should appear as a series of dash lines or slots spaced along one line. The center slots should be much brighter, while the outer dash lines diminish in intensity. Rotate the optic mount in the laser chassis.

The pattern produced on the wall is the result of the laser beam being broken down into two separate and independent beams by the optic mount. From each slot a beam travels outward and diverges as it moves from its slot toward the wall. The beams recombine at the wall and — because they are precisely the same wavelength — they create an interference pattern of alternating bright and dark spots. (For more details about diffraction, see page 10 of this manual.)

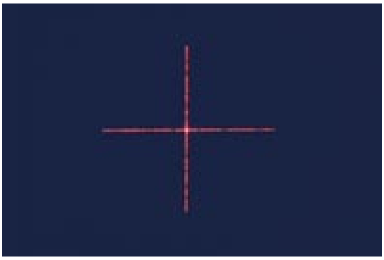
Multiple-slit (blue)



A more dramatic visual effect results from diffraction wave interference if the number of slots is increased from two to a continuous array. The laser light pattern will appear similar to the one produced by the previous optical mount, only this time the dots will be much brighter and the outer dots will diminish in intensity. The spacing between each dot will also increase.

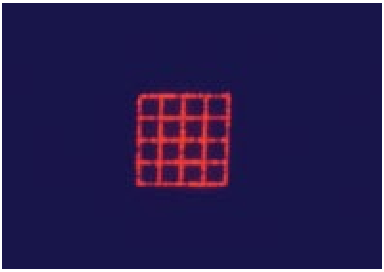
Attach the blue optic mount to the laser. The pattern that you observe on the wall should be similar to the picture shown at the right. The individual light spots should be much more intense than with the previous optic mount and more of a round spot than dash. This increased definition is caused by a greater number of slots contributing to the diffraction light pattern.

Crosshair (silver)



This optical mount will offer the first demonstration of how the simple diffractive effect can be expanded to create very useful light patterns. Attach the silver optic mount to the laser. This diffraction optic lens creates one perpendicular line and one horizontal line that intersect to form open quadrants as shown. The intersection of the two lines forms a brighter image (dot) at the point where they cross and can be used in various alignment or positioning applications. If a precise spot needs to be chosen or analyzed, a crosshair pattern creates a reference area and makes positioning easier to attain than when using only a dot. In the medical field this helps pinpoint an area of the body that needs radiation treatment for cancer. Technicians use this directed pattern for X-ray film placement on specific body parts. Other applicable fields are the military, science, industry (for positioning in manufacturing) and in construction.

Grid (green)



The concepts used in creating the crosshair pattern can be further expanded to generate more complex images. Patterns such as these would be impossible with conventional optical elements, as you will see next.

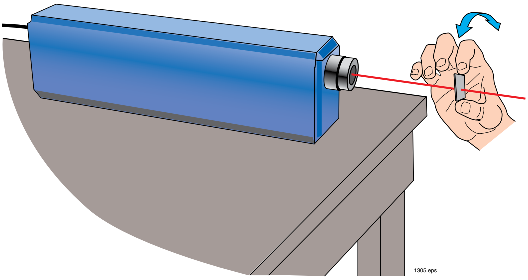
Thread the green optic mount in the laser optics mount. Observe the resulting pattern. This diffractive optic element creates one large outer square with 16 inside symmetrical squares interlocking to form a grid. As with the silver mount, grid patterns such as these can be used in many areas including industry, for exact positioning of tools in manufacturing, creating map quadrants of various sizes, military target positioning and hospital use for X-ray placement. Can you think of other possible uses?

The previous diffractive optical mounts produced images with straight lines or dots. However this is not the limiting case. Diffraction optics can be used to create arcs, circles, diagonal lines, etc., to provide entertaining laser light shows or advertising displays as well.

Polarization (black)

An often overlooked and misunderstood property of light waves is polarization. For a quick overview of polarization and waves, go to page 11. We will help you visualize polarization and its effects on light with this mount. The laser you will likely have used in these experiments thus far is a helium neon or diode laser. Helium-neon lasers can produce light that is random, uniformly or linearly polarized. Diode lasers always produce linearly polarized light. The black optics mount in this kit has a linear polarizer attached to its rear surface which will aid in determining the type of polarized light your laser produces. Install the black optic mount in the laser. Observe the optical beam pattern on the wall for about 60 seconds. If the beam varies in brightness your laser is randomly polarized.

If the spot is constant, your laser is either linearly or uniformly polarized. To determine which, rotate the black optic mount a complete 360 degrees. If two rotational positions produce an output beam that is very, very dim, your laser is linearly polarized. If the brightness of the laser beam does not change during rotation, your laser is uniformly polarized and produces light of all linear polarization angles. What type of polarization does your laser produce?



Rotate the black optic mount in the laser so the laser beam is clearly visible. In your optics kit find another piece of linear polarizer material, a thin piece of gray plastic approximately 25 × 25 mm (1 × 1 inch). Hold the second polarizer with your hand perpendicular to the laser beam so the laser beam passes through the polarizer. Now rotate the polarizer in your hand while observing the laser beam on the wall. At some point the intensity of the laser beam should diminish until it almost disappears. This is the point at which the linear polarizer plane films are at right angles to each other.

Polarizing filters are used in sunglasses, photography and many other applications. When polarizing light panels are placed in office buildings they can reduce lighting levels and still produce better viewing conditions. This both conserves energy and creates more comfortable working conditions. Polarized sunglasses reduce glare from water because the majority of light reflecting from water is in one plane.

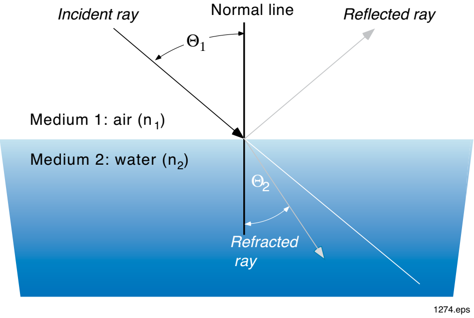
Fiber Optics (gold)

The gold optic mount holds the optical fiber cable found in your kit. Identify the optical fiber cable and its end which has a small black plug, then insert the plug into the hole in the gold optic mount. Hold the cable straight and observe the laser light coming from the fiber end by holding your hand or a piece of paper near the fiber end. (Do not look directly at the fiber end. This laser energy still can be harmful.) Now loop the cable so the light must travel in circles to exit, and again observe the light coming from the end of the optical fiber. Notice that no matter what shape the fiber forms, light continues to travel through the cable. How did this occur? For more information on the physics of optical fiber and its light-carrying capabilities see page 12.

GEOMETRIC OPTICS

Geometric optical elements are those that bend or reflect light based on geometry principles and physics laws pertaining to refraction/reflection. Geometric optical elements include most common lenses or mirrors as found in microscopes, telescopes, binoculars and eyeglasses. Fundamental to this concept is all optical materials having a property called refractive index (n). A material's refractive index is defined as the ratio of the speed of light in a vacuum, to the speed of light in the material.

$$n = \frac{\textit{velocity in vacuum}}{\textit{velocity in material}}$$

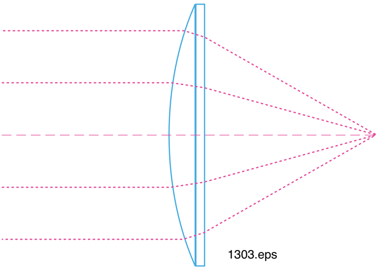


The second fundamental property in geometric optics is prescribing that light travels in straight lines through all optically transparent materials. However, when light travels from one material to another, something different happens. If the refractive index of the two materials differs, light is bent as it passes through the boundary—for example, passing from air into glass, as shown above. The amount of bending depends on the refractive indices of the two materials and the angle (geometry) of the incident ray striking the boundary between the two mediums. The angles of incidence and refraction are measured from a line perpendicular to the surface. The mathematical relationship between the incident rays and the refracted rays was first predicted by a scientist named Willebrord Snell (1591-1626). Snell's Law describes the bending of light passing through a boundary between two optically conductive materials. Mathematically, Snell's Law states:

$$n' \sin\theta' = n'' \sin\theta''$$

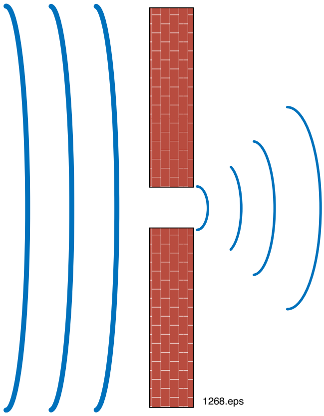
where n' and n" are the refractive indices of the initial and secondary material, respectively, while θ' and θ'' are the angles of incidence and refraction, respectively.

Expanding this concept to a group of parallel light rays traveling through air and striking a piece of glass with a curved polished surface it is obvious that the light rays would bend. (Glass has a refractive index of 1.5 and air 1.0.) The amount of bending that occurs depends on the geometry at which the light rays strike the curved surface as shown to the right. This bending of light rays causes optical lenses to focus light, as shown at right.

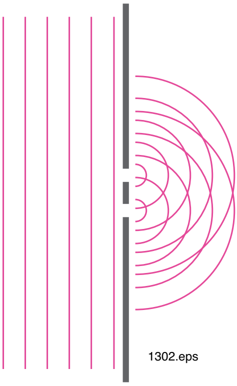


A mirror is an optical lens whose surface is covered with a reflective coating such as aluminum or gold. Light rays striking a mirrored surface reflect at an angle equal to the incident angle.

DIFFRACTIVE OPTICS



In the section on geometric optics, we defined light as traveling only in straight lines. That is true—but primarily in cases where the wavelength of light is many times smaller than the lens, mirrors, or other surfaces it encounters. This characteristic changes as objects become smaller and approach the same size as the wavelength of light. When waves pass through a slit as shown at the right, we might think they would continue on their way in straight lines. Not so. When waves pass through a small slit similar in size to their wavelength, they diffract or bend, as shown in the illustration. The amount of bending depends on the size of the wavelength of light compared to the size of the opening. You may have observed how incoming ocean waves react when they encounter a breakwater or reef. They bend, then spread out. If wave diffraction were not a reality you could not hear someone talking from across the room unless they were directly facing you.

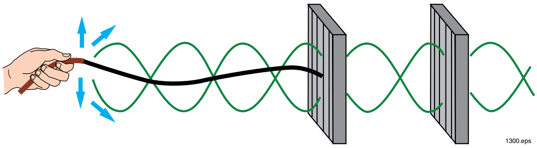


Interference is another wave effect created when two or more identical waves encounter each other as shown in the figure at the left. In some areas the crests of the two waves combine easily. But in other cases, the wave crests and troughs meet in a destructive collision so they instantaneously cancel each other and nothing remains. The combination construction/destruction pattern was produced when you used the turquoise mount. Interference occurs only when wavelengths are identical, as when produced by a laser. You will never see interference caused by light from an incandescent or fluorescent light bulb because wavelengths from those sources are not identical.

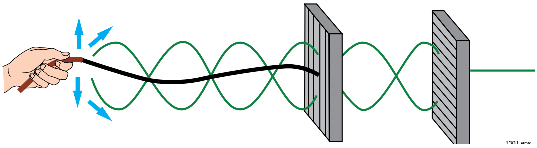
As with most scientific principles, fundamental concepts in this area can be expanded and refined. With the blue optics mount this is exactly what was done. Two slots were expanded to an array of slots. The resulting beam pattern became multiple small dots, rather than a series of dashes. If we were feeling creative, our next step might be figuring out a way to pass a beam of light through an optical pattern so a more artistic or complex pattern is created, using a combination of diffraction and interference. In fact, these two scientific principles are exactly what we used in the silver, green and gold mounts.

POLARIZATION

All waves possess one of two different types of motion. Sound waves are compressional motion (like compressing, then releasing a spring). Light waves, however, are transverse. To visualize transverse waves, imagine holding one end of a 10-foot-long rope in one hand. The other end of the rope is fastened to a wall, and you are pulling it tight, so it extends in a horizontal line. Now move that hand up/down, right/left and circular in random patterns. With these motions you are creating a visual model of a transverse light wave. Energy, or light, begins at your hand and ends up at the wall. All energy or waves that you created in the rope are unpolarized because there is no defined pattern or motion. Sunlight is unpolarized, as is light from most light sources except lasers.



Conversely, a linearly polarized wave travels in a known and nonvarying pattern, as if you were to move the rope only up/down. Unpolarized waves can be filtered into polarized waves if we use special materials with slots or gratings in them. Imagine the rope passing through a grating with only vertical slots, as shown above. The slot prevents sideways motion, but freely allows the vertical components of vibration to pass.



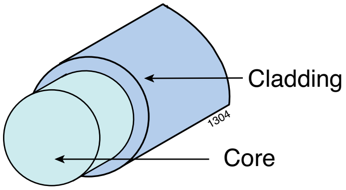
Placing a second vertical grating behind, and aligned with, the first will still allow the vibrations to pass through both sets of slots freely. However, if we turn the second grating to a horizontal position, none of the vertical light/waves exiting the first grating will pass through or be transmitted by the second grating.

The polarizing filter in your optics kit acts like the gratings described above. Imbedded inside the plastic are molecules that allow only light waves of a certain polarization to pass through. When unpolarized light passes through a linear polarizing filter, it emerges as polarized light vibrations in a single plane—although with one-half the intensity.

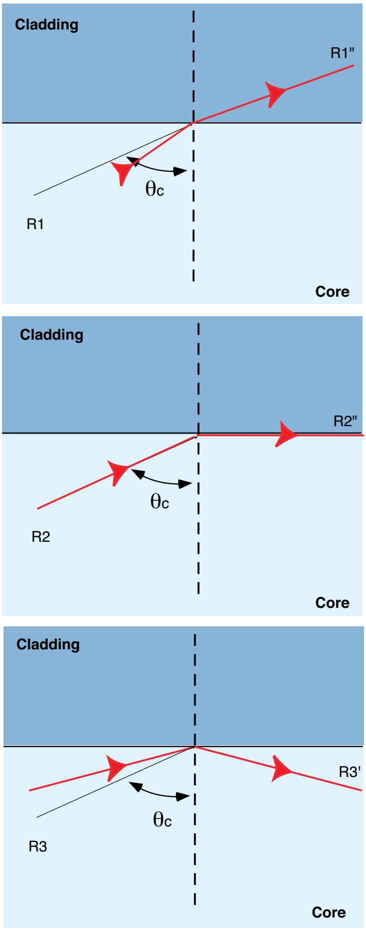
Unpolarized light can also undergo polarization by reflection. Non-metallic surfaces such as asphalt roads, snowfields and water reflect light with a large concentration of vibrations (which we commonly call “glare”) in a plane parallel to the reflecting surface. Light reflected off a lake is polarized mostly in a direction parallel to the water’s surface. Glare often prevents fishermen from seeing fish in the water below. Savvy anglers know that using special sunglasses (containing lenses with a proper polarization axis) reduces glare, and they can easily see fish and other underwater objects. Polarization has a wealth of other applications besides its use in glare-reducing sunglasses. In industry, polarizing equipment is used to indicate stress in transparent plastics. Polarization also is used in the entertainment industry to produce and show 3-D films and videotapes.

OPTICAL FIBER THEORY

Fiber optics is the most rapidly growing portion of optics study in the world. It has grown so dramatically that some people may not think of it as even being part of the optics field. In terms of data communications they could be right, because fiber optic communications utilizes electronic and laser technology, in addition to optical fiber.



The illustration above depicts the construction of basic communication optical fiber, with concentric layers of materials called the core and cladding. These materials are bonded to each and are always composed of different materials because they must have different refractive indexes. With the wave guides contained in this kit the cladding layer is air. The acrylic bars are the cores.



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In optical fibers, the outer material always has a lower refractive index than the inner layer. Visualize a light ray — traveling at a specific angle — as it strikes the boundary between higher and lower refractive index materials. As the light ray enters the lower refractive index material, it bends away at an increased angle, as shown. If the entry angle of the light ray increases, eventually the exiting ray will be parallel to the horizontal boundary between the materials. This entry angle is called the critical angle (θc). Any further increases in the angle of the incident (entry) ray will actually cause the light rays to reflect back into the material with larger refractive index — the core. This reflection is commonly called “total internal reflection” and is the basis for the theory of how light travels through optical fiber. Because the cladding layer surrounds the core, the light is confined to two dimensions and travels lengthwise (also “rebounding” from side to side) from one end of the fiber to the other.

Total internal reflection is essentially “loss-less” reflection. No light is lost at each successive reflection within the fiber, which makes this concept very suitable for transmitting light over long distances. Any minor loss of light in optical fiber is caused primarily by impurities in the core material.

Commercially available optical fiber is usually made from glass or plastic. Optical fiber can carry many times more information — faster and over longer distances — than conventional copper wire, and it is far less vulnerable to electromagnetic interference. Other advantages of fiber optics include ease of installation and the ability to transmit data with extremely low error rates. Optical fiber also does not “attract” lightning strikes, since it is not electrically conductive.

Table 1. Refractive indices of some common materials.

MATERIAL	VALUE
Air	1.00029
Water	1.33
Glass	1.4 - 1.8
Silicon	3.5
Acrylic	1.49
Diamond	2.0

WARRANTY

Industrial Fiber Optics products are warranted against defects in materials and workmanship for 90 days. The warranty will be voided if the components have been damaged or mishandled by the buyer, including as a result of dropping or scratching of optical surfaces.

Industrial Fiber Optics' warranty liability is limited to repair or replacement of any defective unit at the company's facilities, and does not include attendant or consequential damages. Repair or replacement may be made only after failure analysis at the factory. Authorized warranty repairs are made at no charge, and are guaranteed for the balance of the original warranty.

Industrial Fiber Optics will pay the return freight and insurance charges for warranty repair within the continental United States by United Parcel Service or Parcel Post. Any other delivery means must be paid for by the customer.

The costs of return shipments for products no longer under warranty must be paid by the customer. If an item is not under warranty, repairs will not be undertaken until the cost of such repairs has been approved, in writing, by the customer. Typical repair costs range from $10 - $50 and usually require less than one week to complete.

When returning items for analysis and possible repair, please do the following:

- In a letter, describe the problem, person to contact, phone number and return address.
- Pack the laser, power adapter, manual and letter carefully in a strong box with adequate packing material, to prevent damage in shipment.
- Ship the package to:

INDUSTRIAL FIBER OPTICS
1725 WEST 1ST STREET
TEMPE, AZ 85281-7622
USA

SHIPMENT DAMAGE CLAIMS

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. If shipping damage has occurred during shipment, please do the following:

- Make a note of the carrier company; the name of the carrier employee; the date; and the time of the delivery.
- Keep all packing material.
- In writing, describe the nature of damage to the product.
- Notify the carrier immediately of any damaged product.
- Notify the distributor from whom the purchase was made.

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 disassemble or try to adjust the laser's internal components. Electric shock could result.