Modeling

Fig. 1. Streetlighting in the smaller scales is one area where fiber optics really shine. With overhead lights using a dimmer, the effect can be startling.

with fiber optics

All about guiding light into tiny places

BY D. DEREK VERNER

Fig. 4. Vehicle headlights throw a concentrated beam because of the fibers' directional quality.

AS model railroad scales grow smaller and detail standards become more exact, the difficulty of scale illumination increases. Microminiature lamps have been developed for medical and aerospace applications, but their cost is usually prohibitive. Some modelers have employed ultraviolet light and fluorescent paints with some success, but this system lacks intensity and individual lamp control. Light-emitting diodes, a recent development of computer technology, offer interesting possibilities. So far, however, colors are limited to red, yellow, and green, with only the red-emitting units available in the small T-¾ size.*

So far, the most effective solution seems to be in the field of fiber optics. Fiber optics, or "light pipes," are filaments of a transparent material that transmit light from one end to the other even though the filament may be bent or tied in a knot. The phenomenon has been familiar since the 19th century, when the British physicist John Tyndall (who, incidentally, began his career as a railroad engineer) demonstrated that a stream of water could transmit light.

How it works

The principle by which fiber optics works is called total internal reflection. It is illustrated in fig. 2. Light entering one end is reflected back and forth from the walls until it exits from the other end. The familiar "edge lighting" used on radio dials and plotting boards uses the same principle. In an edge-lit panel, all the light theoretically bounces back and forth between the surfaces and exits only at the edges. If, however, one of the surfaces is scribed or painted, light reaching it is partially scattered as shown in fig. 2. This effect is what makes the numerals on a radio dial or the grease-pencil markings on a plotting board visible. The trouble is that minute scratches or even dust on the surface also causes light to leak out. What Du Pont has done with its "Crofon" fiber optic filaments is to coat the core material with a different clear plastic which has a lower refractive index. Now the reflective surface is at the interface of the two clear plastics rather than at the plastic-and-air interface, as illustrated in fig. 3. This prevents dust or minor surface damage from causing light leakage and even allows the surface to be painted providing the sheathing material is not damaged.

Du Pont and now International Rectifier are manufacturing the material in a number of forms. Of major interest to model railroaders are monofilament fibers in 10-, 20-, 30-, and 40-mil diameters and jacketed bundles of 10-mil fibers containing 7, 16, 19, 32, 37, 48, or 64 individual filaments. The fibers are available from a number of sources: see box on page 56. They are rather expensive in the larger diameters. However, the amount of light transmitted increases as the square of the diameter, so the larger sizes are well worth the difference in price. A 40-mil filament, for example, can carry 16 times the amount of light that the less expensive 10-mil filament is capable of transmitting.

Figs. 2 and 3 also illustrate the two most serious disadvantages in using fiber optics. They both have to do with the critical angle: that is, the angle at which light no longer is reflected but passes through the surface of the fiber. For the type of plastic used in Crofon, this angle is 67 degrees. This means that the filament accepts light only from a cone-shaped area approximately 70 degrees from its end as shown. The light emitted from the other end of the fiber is also limited to this cone shape. In practice, the cone is even smaller, because as the light source moves off the fiber axis it is reflected more and more, suffering a slight loss at each reflection. This is shown in fig. 2. It results in the brightness, falling off rapidly as the observer moves off the axis of the fiber end. For some applications, such as searchlight signals or the automobile headlights shown in fig. 4, this is an advantage. For most model railroad applications, however, it is a serious drawback because the lights are almost invisible from the side. This article deals with a number of ways to overcome this problem.

The second disadvantage, as shown in fig. 3, is that sharp bends in the filament cause the light to strike the interface at an angle greater than 67 degrees and exit from the fiber. This is a more difficult problem to deal with and one that must be overcome by careful design of the lighting fixture. In general, sharp bends should be avoided wherever possible. One exception to this rule will be discussed later.

*This letter and number classification system is used by lamp manufacturers to specify bulb dimensions. The letter (or letters) refer to the shape, and the number is the diameter in eighths of an inch or in units of 3.2 mm. Thus, a flashlight lamp designated G-3½ is spherical and measures 7/16" or 11 mm. in diameter.

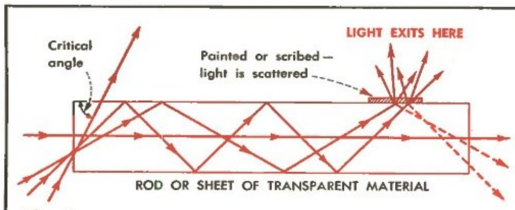

Fig. 2

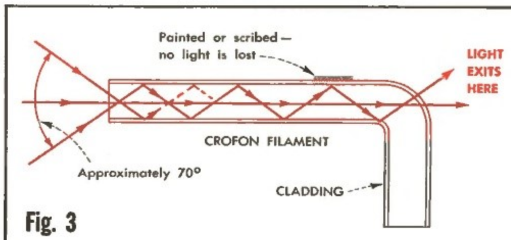

Fig. 3

Fig. 5. There is literally no size limitation. This lamp alongside a quarter is suitable for use in Z scale, but it is actually intended to illuminate the backyard patio of an HO scale house.

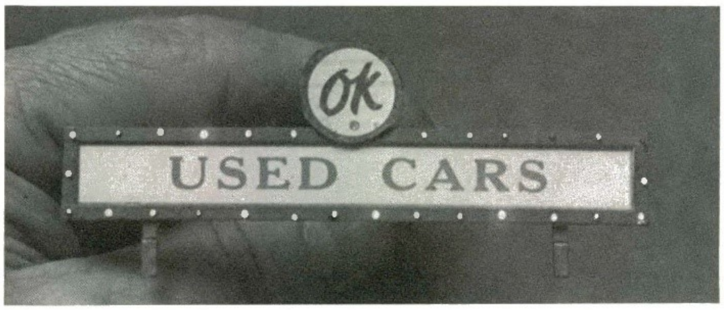

Fig. 6. Multistrand fibers make advertising signs like this one simple and cheap to illuminate.

Fig. 7. This parked truck uses individual fibers run to a lamp located under the layout. If an Ulrich metal truck body were used, the lamp could be housed inside the vehicle, thus saving on the length of the fibers required. With lamp plus battery the truck could then be moved about.

The advantages of fiber optics in scale illumination are many. First and foremost, of course, is the extremely small size of the apparent light source. Fig. 5 shows a streetlight that is suitable for use in Z scale. Forty-mil fiber scales down to less than 4" in HO scale, making possible the modeling of individual lightbulbs. Fig. 6 shows a used-car dealer's sign with colored bulbs that are accurate reproductions of 100-watt prototype lamps. This was made from 32-strand jacketed fiber with the ends treated as described later.

The second advantage is the total lack of heat. This means that lights can be embedded in plastic locomotives, vehicles, or structures without fear of melting the plastic. Fig. 7 shows a plastic truck body with a complete set of marker, classification, and tail lights.

A third advantage is color temperature. Most lights on model railroad layouts are operated at considerably reduced voltage to extend lamp life and reduce heat buildup. This is good practice but tends to make all of the lighting in the layout appear yellowish. With fiber optics a full range of color temperatures can be produced because heat is not a problem and lamp replacement can be made a simple procedure.

Another advantage is that a single bulb can be used to produce literally hundreds of individual lamps. The final advantage, and one of the biggest, is the ability to program the lighting by relatively simple means. Programing and control techniques will be discussed in detail in part 2 of this article. Essentially, they consist of mechanically interrupting the light to the input ends of the fibers. For example, a motorized disk containing colored gels and opaque areas can be interposed between the light source and the termination block of a large number of fiber optic filaments. As the disk rotates, it turns individual lamps on and off or

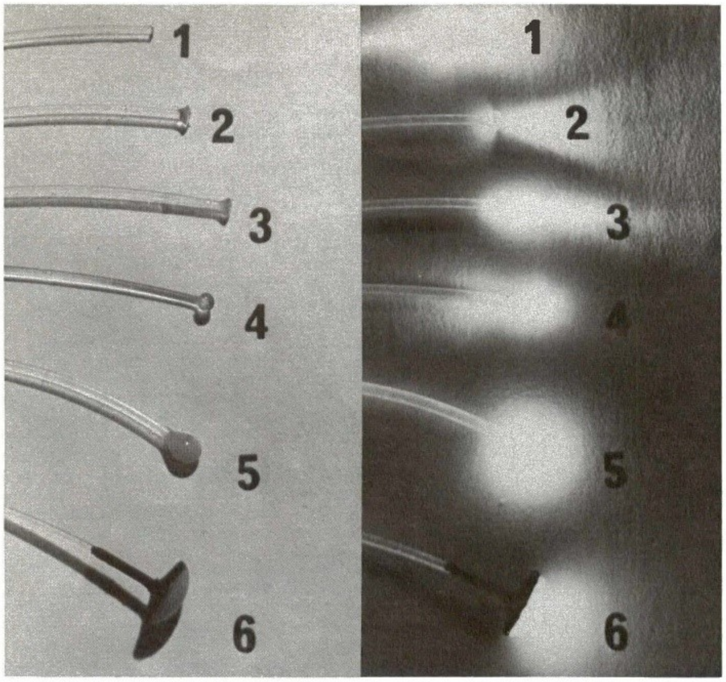

Fig. 8. The ends of the fibers can be treated in many ways to obtain varying effects, as author Derek Verner explains in the text. Experiment with each to determine which works best for you.

changes their color. By careful arrangement of this mechanism, all sorts of effects are possible, from chase lights on movie marquees to fireworks.

Termination techniques

Fig. 8 shows a number of optic fibers with various methods of termination. No. 1 is an untreated filament that is simply cut off with a pair of diagonals. No. 2 has been expanded by holding a lighted cigaret about $^{1}/_{8}$" from the fiber end as shown in fig. 9. This causes a mushroom-shaped bulge to appear. For those who have given up smoking, a soldering iron will work almost as well. Do not touch the fiber to the iron, but hold it close enough for the heat to expand it, forming a sort of lens that is visible from a wider angle.

No. 3 in fig. 8 has been expanded and dipped into a solvent type of cement such as ethylene dichloride. This has the effect of destroying the cladding and slightly crazing the surface, allowing the light to be seen from all directions.

No. 4 is a special case. It produces an extremely bright point of light that must be aimed at the observer. It is useful in a lamp located at the rear of the layout. To produce it, make a sharp right-angle bend near the end of the fiber by holding it over a cigaret or soldering iron. Clip off the fiber about $^{3}/_{16}$" from the bend and use the heat source to mushroom the end. In mounting the fiber, point the bent end toward the viewer. The first and fifth streetlamps in fig. 1 were made using this method. The light, as explained earlier, leaks out at the bend; but because it is so close to the mushroom lens, it causes little light loss and produces a very bright, highly directional source of light. It is especially useful in signal lights where the fibers run up inside the signal standard. Previous instructions on illumination of signal lights required the fiber to extend out from the back of the signal head in a highly unprototypic fashion.

No. 5 (in fig. 8) uses a drop of clear epoxy or polyester resin that has a small quantity of white (or other translucent pigment) added. Fig. 10 shows how this is done. The polyester resin is the type used for clear castings or embedments; it is available from many handicraft supply houses. It is the same type used for realistic lakes and rivers on many layouts. Ordinary polyester resin such as the type sold for fiberglass lamination will work as well, but its slightly pink color is not altogether desirable. Even though the polyester casting resin

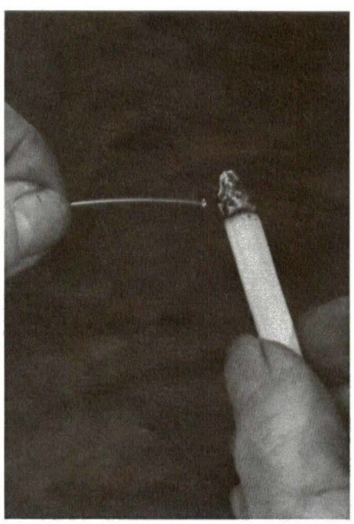

Fig. 9. Heat from a cigaret causes the end of a fiber to form a mushroom-shaped lens. Or, if you don't smoke, you can use a soldering iron.

Fig. 10. Small lamp-shaped beads can be formed with epoxy or with polyester resin and pigment.

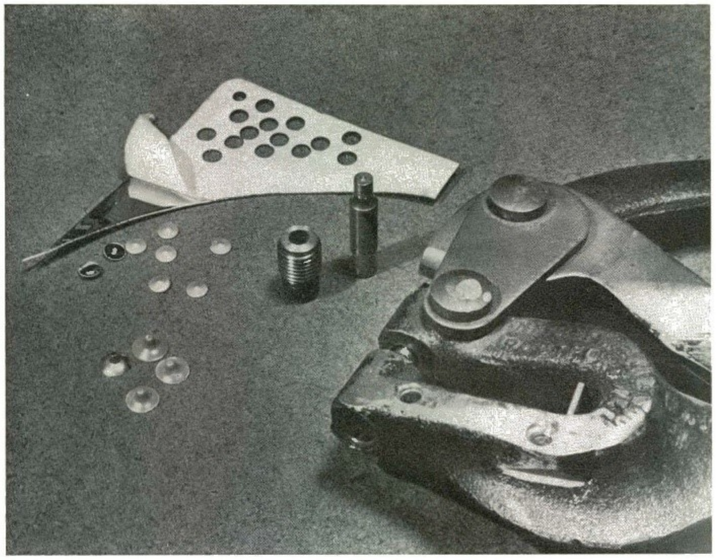

Fig. 11. Small reflectors can be mass-produced by means of a metal punch such as the one shown.

is less viscous than the 5-minute clear epoxy, it holds its shape better during curing. Epoxy tends to flow more and may require that the fiber be shifted and rotated continuously while it sets up, so as to prevent a distorted bead from forming. The white pigment, available from the same source as the casting resin, should be used in microscopic amounts. All that is wanted is enough to scatter the light, not enough to reduce the translucency of the bead. Mix a small batch of the resin; then dip just the tip of a toothpick into the pigment and mix it thoroughly into the catalyzed resin. Apply the mixture to the mushroomed end of a fiber optic filament. Allow the bead to harden in an inverted position. This will produce a lightbulb-shaped bead that will glow brightly when the end of the fiber is illuminated. Spherical shapes or larger beads may require that the filament be turned during curing to prevent sagging.

The final filament in fig. 8 (no. 6) was produced by using the pigment-and-resin mixture poured into a reflector. The reflectors or light shades for many of the lamps shown in the photographs were produced by the use of a metal punch as shown in fig. 11. This punch, manufactured by the Whitney Metal Tool Co. in Rockford, Ill., has a small centering point which produces a neat dimple in the exact center of the punched-out disk. An ordinary paper punch can also be used and the dimple added by means of a center punch.

The reflectors can be punched from styrene, Plastruct ABS, or sheet metal. The material in fig. 11 is a photographic ferrotype plate which is made of thin sheet brass chrome-plated on one side. It makes ideal reflectors. Other good sources of miniature reflectors are metal button shells, upholsterer's tacks, and the small brass flared eyelets sold by Campbell Scale Models. They can also be vacuum-formed over various shapes, using a Mattel Vacu-Form — a toy popular a few seasons back that has many applications in modelmaking. Fig. 11 also shows some reflectors formed over the Campbell units by means of the Vacu-Form.

To return to the final filament termination in fig. 8: Drill a small hole in the top of the reflector; slip it over the filament; mushroom the end and set it, face up, on a suitable support. Using a toothpick, carefully apply the pigmented resin mixture to the interior of the reflector until a neat edge-to-edge mound is formed.

The pigmented resin can also be cast around the end of a fiber as shown in fig. 12. Here, a mold was made in RTV (Dow Corning) from the cutoff head of a Selley traffic light (no. 196). First a .030"-diameter wire was inserted into a hole drilled in the bottom. Then a two-piece mold was made in a small plastic box with the parting line located along the length of the wire. A 30-mil fiber was prepared by dipping about 3/8" of the end into ethylene dichloride to break down the cladding. The fiber was placed in the mold with the prepared end inside the head. The mold was then filled with the pigmented resin and the resin was allowed to set. This produced an exact duplicate of the Selley head except that when the free end of the fiber was illuminated the entire head glowed. Then red and green transparent paints were applied to the appropriate lenses and the remainder of the head was painted with dark green Polly S. This produced an accurately scaled traffic signal that shows the correct (but unchanging) aspect in all four directions. The same casting technique can be used for other special-purpose lighting fixtures.

The method used on the old-fashioned streetlamps shown in fig. 13 is yet another termination technique. Chuck a small-diameter white or clear lucite rod in an electric drill. Using a file and an emery board, taper the end of the rod. With the piece still chucked in the drill, bore a hole of the appropriate size (no. 80 for 10-mil, no. 75 for 20-mil, no. 68 for 30-mil, no. 59 for 40-mil) in the end of the rod as shown in fig. 14. With a razor saw, cut off the finished piece. This forms the head of the lamp. The Crofon filament is solvent-cemented into the drilled hole. The top cap is punched from Plastruct sheet and

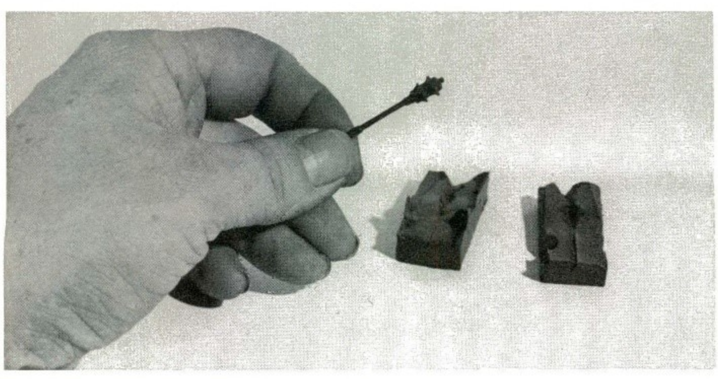

Fig. 12. Casting pigmented resin over the end of a fiber can produce complex illuminated shapes.

Sources of supply

The following suppliers can provide fiber optic material and accessory items:

Edmund Scientific Co., 700 Edscorp Bldg., Barrington, N. J. 08007. Fibers, input lenses, transparent paints, and many other items of interest. Free catalog.

Olson Electronics, 260 S. Forge St., Akron, Ohio 44327. Mono- and multifilament fibers. Light heads and accessory items. Free catalog.

Micro Lite Industries, P. O. Box 466, Millville, N. J. 08332. Monofilament fibers, lamps, transparent paints, etc. Catalog 35 cents.

Runei Associates (see your dealer). 10-, 20-mil fiber, multifilament fiber, switchable lighting system, accessory items.

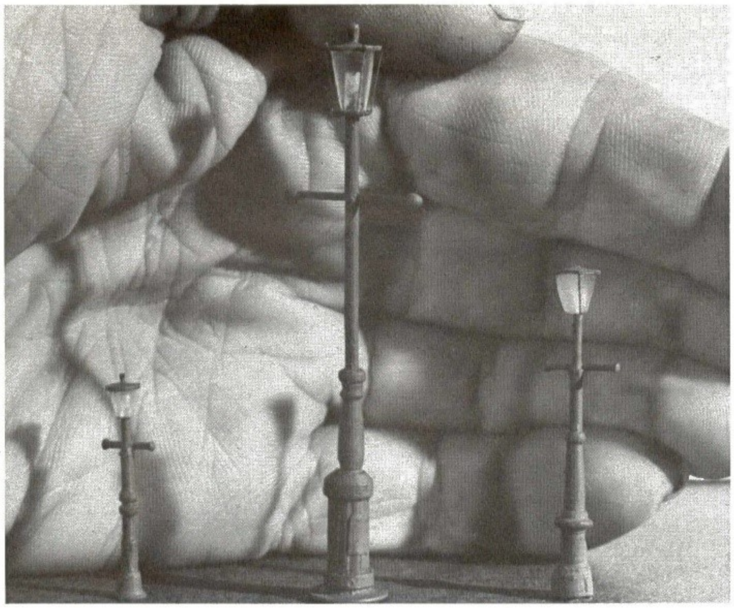

Fig. 13. Because they require no sharp bends, these streetlamps can be made to glow very brightly.

is cemented in place with a solvent-type cement.

The largest lamp shown in fig. 13 has a bottom as well as a cap, with support rods formed of styrene filaments. This is a technique that should be in every model-maker's repertoire. Take the casting sprue from a plastic kit and hold it above the flame of an alcohol lamp or candle until it softens. Quickly stretch it and it will form a long, thin filament. Hold it steady until it cools. Filaments of almost microscopic thinness can be made in this way. Because the material can be solvent-cemented with no fillets, it can be used for extremely fine detail work. The finials and the crossarms for the two smaller lamps in fig. 13 were made in this fashion. The knobs on the ends were created by means of heat applied with a cigaret. The uprights of the two small lamps are the actual Crofon filaments themselves and the crossarms are simply solvent-cemented in place. The upright for the largest lamp is 1/16" brass tubing and its crossarm is a length of brass wire soldered into a cross hole drilled through the tubing. The tubing was drilled out to permit passage of the 30-mil Crofon fiber. The knobs on the ends of this crossarm are blobs of epoxy.

The bases of the lamps in the photographs were made in a number of ways. Some were turned from brass; others were assembled from eyelets and small-diameter tubing. The ribs on the base of two of the lamps were formed using an interesting material available in most hardware stores. It is aluminum foil tape sold for repairing heating ducts. It comes in 3" widths with an adhesive backing protected by a plastic-coated paper. It is excellent for simulating corrugated roofing and siding. Simply place it, backing and all, over a corrugated surface such as a piece of Vollmer plastic roofing and burnish it into the grooves with a pencil. Peel off the backing and affix it in place. The bases of the lamps were simply wrapped with a few turns of the scored tapes.

Thin strips of masking tape can also be used to create decorative rings on the lamp bases. The purpose of this article is not to give complete instructions for duplicating the author's efforts but rather is to give some general techniques which can be adapted to your own designs and needs.

Shaping filaments

Fibers supplied on small-diameter spools are difficult to work with because they tend to curl like coil springs. In situations where the filament itself forms some part of the lamp fixture, it is important that this curvature be removed. This can be done by careful application of heat. The plastic begins to soften at 175 degrees F. but its cladding will be destroyed at higher temperatures. Hair driers and hot water have been suggested for shaping the fibers, but the best method seems to be a kitchen oven with a low-level setting. Adjust the thermostat for 175 degrees. Lengths of fibers can be straightened by suspending them in the oven with weights at their lower ends. Check frequently; and as soon as the curl disappears, remove them and allow them to cool with the weights still in place.

Local shaping, such as that in the modern highway lamp in fig. 1, can best be done with a large-area heat source such as an electric clothes iron. Adjust the iron to its highest setting and hold the filament about 1/2" above the inverted iron. As soon as the plastic begins to soften, remove it from the heat source and hold it in the desired shape until it cools. Try to make all bends as gradual as possible and avoid heating the plastic too much in one spot. Overheating will be indicated by the surface's becoming cloudy. Snip off the damaged portion and try again.

Painting

Water-based paints such as Polly S or artist's acrylics work best because they do not react with the plastic and destroy the cladding. A few drops of a wetting agent such as Kodak's PhotoFlo will make water-based paints flow better, permitting smoother results. Despite all handling precautions some surface damage will occur, and light leakage is inevitable. For this reason, it is a good idea to undercoat the final finish with white. This helps reflect some of the leakage light back into the fiber. Transparent dyes or paints can be used at either the source or the output end to produce lights in almost any color desired. In addition to the dyes and paints listed on page 56, the fibers can also be colored with waterproof marking pens. The deepest color saturation, however, is obtained when the proper coloring agents are used.

Light sources

A number of manufacturers supply units specifically for the purpose of illuminating bundles of light fibers. A com-

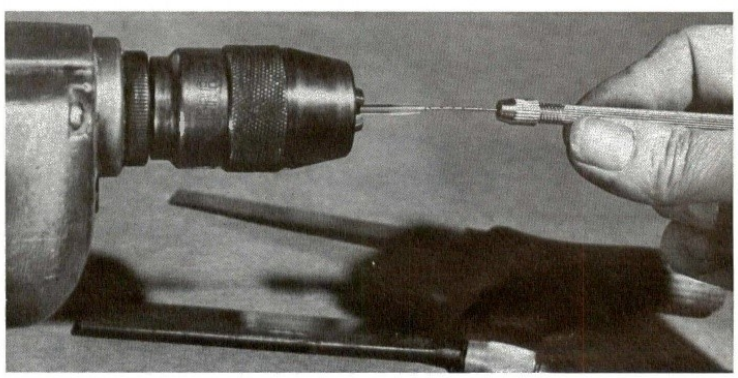

Fig. 14. White lucite for lampheads gives off a suffused glow. Clear material resembles a glass-enclosed light source. An electric drill can be used as a lathe during the shaping operations.

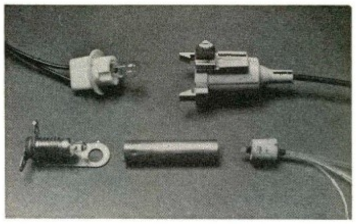

Fig. 15. Illumination of the fiber ends can be done with purchased or homemade light sources.

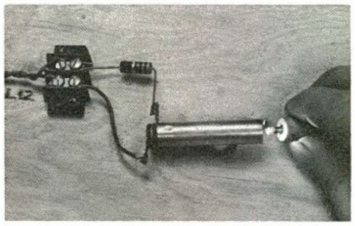

Fig. 16. A dropping resistor or series hookup is required unless lamp matches supply voltage.

mercial single-head unit is shown at the top of fig. 15. It consists of a lamp, a housing, and a lens system. Also available are multiple-head units which accept up to four bundles of fibers, as well as multiple-lamp units which can be sequenced electrically.

A simple homemade unit is shown at the bottom of fig. 15. A screw-base lampholder, available from most electronics supply houses, is fitted with a short length of 7/16" brass tubing. A dimple in the end of the tubing allows it to be screwed onto the threaded shell of the socket. A small cork or rubber stopper inserted into the other end is drilled to accept the bundles of fiber optics. Brightness will be increased considerably if a lensed type of lamp is used. The one shown is a no. 224 supplied for use in penlights. Its operating voltage is 2.15, so a dropping resistor as shown in fig. 16 is required to reduce the supply voltage to the correct value. For a 16-volt supply this is about 68 ohms. Adjust the resistor value accordingly for a different supply voltage. Lensed lamps for locomotive headlights are also available from Kemtron and others for use on higher voltages. The no. 224 was selected because it is inexpensive and available almost anywhere.

Where the individual fibers enter the light source they should be bundled and wrapped with tape or inserted into an eyelet or heat-shrinkable tubing. They can also be cemented together with clear epoxy or "Future" acrylic floor finish. Do not use Duco or any cement that contains a plastic solvent, as this will attack the cladding. "Future" floor finish can also be applied to the ends of the fibers to increase light transmission. The coater supplied with Polaroid film is also suitable for this purpose. A number of manufacturers supply "capping" fluids for this purpose and even suggest abrasive polishing techniques to improve the transmission quality. These, however, are hardly worth the effort involved. Simply heat-polishing the ends with a lighted cigaret works almost as well.

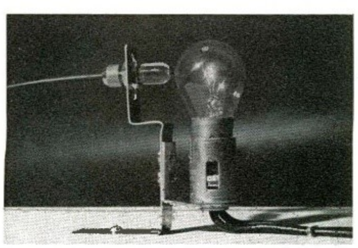

Fig. 17. Automotive and other large lamps can be used with this light-gathering input lens.

Note that the homemade illuminator has no provision for cooling vents. Experience has shown that the brass tube and metal socket serve as a heat sink and radiate sufficient heat to prevent the temperature of the Crofon from reaching the softening temperature of 175 degrees F. If you wish, however, you can drill a few cooling holes in the brass tube without significant light loss. Experiment a little with the position of the fiber ends, moving them in and out or from side to side to obtain maximum brightness at the output ends.

A light-gathering input lens is also available. This consists of a colletlike clamp and a clear lens. This increases the acceptance angle of the fibers and protects them from heat damage, permitting larger light sources to be used. Fig. 17 shows a homemade fixture using a 12-volt automotive lamp. The input lens is mounted in a slot as shown to permit adjustment for maximum brightness. Although only one lens is shown on the unit in the photo there is no reason why the lamp cannot be completely surrounded with lenses, each illuminating its own bundle of fibers.

Both for economy and for maximum brightness, keep the fibers as short as possible. It is cheaper to add another light source than to run a fiber several extra feet to reach an existing one. Location of the light sources will depend upon the application. They should be placed in easily accessible locations to facilitate lamp replacement. Under the layout is ideal — and almost mandatory for the streetlights shown in this article.

Fig. 18 shows an Alexander coaling tower fitted with two exterior lights. In this case the structure already had interior lighting, so the fibers were merely inserted through drilled holes and positioned so as to pick up light from the interior bulbs. Fig. 19 suggests a method of interior illumination in highly detailed interiors. Floor, desk, and table lamps; ceiling fixtures; even fluorescent tubes (using the solvent dip method) — in fact, almost any type of prototype lighting imaginable — can be modeled.

The methods described here can be applied to all sorts of miniature lighting effects along your right of way. With a little imagination and a few feet of fiber optic material you can create a new dimension of realism. Order some material in various diameters and do a little experimenting — it will be an illuminating experience.

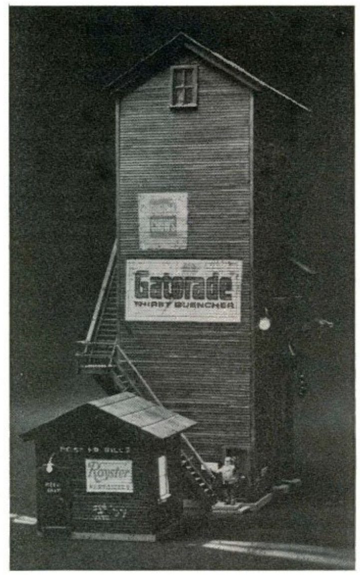

Fig. 18. Lighting a structure exterior is one of the easiest things to do with fiber optics.

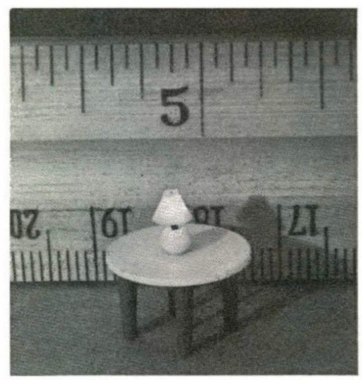

Fig. 19. Where interiors are highly detailed, include a few small table and floor lamps. A bead and a white lucite turning were used here.

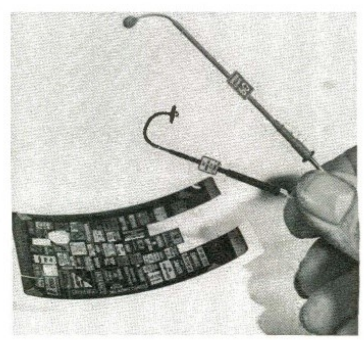

Fig. 20. Signs for streetlights are cut from a color photograph that was made by shooting the pages of a prototype sign supplier's catalog.