A Method of Illumination of Bicycles and Clothing
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Introduction

I have been exploring ways of illuminating my bicycle and clothing so that I can be easily seen at night.

My first attempts at illuminating clothing was by using Christmas lights, starting first in the 1960's with strings of regular 115 volt Christmas lights. This had the severe disadvantage of requiring me to be close to a 115 vole electrical outlet. This made things very inconvenient. Furthermore, the Christmas lights of that era (1960's) were tungsten (incandescent), which made them very inefficient.

Following my attempts at lighted clothing using Christmas lights, I used Electroluminescent Wire, called El-Wire.¹

The following diagram shows the basic operation of El-Wire:

![Diagram of El-Wire](image)

The high voltage / high frequency electrical current excites the phosphor. The phosphor emits light. The light passes through the colored PVC sleeve, giving you the color of the El-Wire.

I encountered problems with El-Wire almost immediately after I started using it.

The first, and most significant problem was that it was not durable enough to be used on clothing. It is fine for a stationary piece of art where it is not flexing all the time. For clothing, it would wear out, often after only one or two days of being worn on clothing. The construction of El-Wire consists of a solid copper wire, around which a very fine wire filament is spiral wound. The fine wire filament is very fragile. The phosphor coating can be easily cracked. If either the phosphor coating is cracked, allowing the fine wire filament to touch the solid copper wire core, or the fine wire filament breaks (due to bending or pressure on the wire), the El-Wire no longer glows and will need to be replaced.

The second problem was that it used a high voltage. The illumination is from electrical stimulation of a phosphor coating on the wire. This needs a high frequency and high voltage (90 volts at 1000 cycles), which is a shock hazard, especially when worn in the rain.

The third problem is that the colors tend to be 'cold'. The light source for El-Wire; the phosphor; is a bluish white color. The colors are rendered by using colored PVC sleeves over the phosphor. Because of the bluish white color of the phosphor, rendition of the 'warm' colors such as red, yellow, and orange are poor.

The current technology that I use is a combination of high power light emitting diodes\(^2\) (called LED's) and side emitting optical fiber\(^3\).

The bright LED is fastened to one end of the optic fiber. The LED's light shines into the fiber at the end and then is dispersed from the optic fiber throughout its length. The following diagram shows the basic operation of the LED / side emitting optic fiber technology:

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\(^2\) A source for high power LED's as well as good information is at [http://www.luxeonstar.com/](http://www.luxeonstar.com/)

\(^3\) A source for side emitting optic fiber is at [http://www.fiberopticproducts.com/Sideglow.htm](http://www.fiberopticproducts.com/Sideglow.htm)
The combination of LED's and side emitting optical fiber has four main advantages over El-Wire.

The side emitting optical fiber is plastic. It can bend. There are no thin phosphor coatings or delicate fine wire filaments.

The LED's operate at a low voltage. The individual LED's need about 2 to 3 volts. There is no shock hazard.

LED's are available in many colors. The colors of individual LED's are very clean colors. The colors are generated by electrical action on special 'doping' of the silicon inside the LED. Because the color is generated by the LED itself, no special coatings or color bulbs are needed. The rendition of the reds, yellows, and oranges are far superior to those from El-Wire.

A pleasant effect can result from fastening LED's at both ends of a piece of optic fiber; each LED a different color. For example, if you fasten a red LED at one end and a blue LED at the other end, you will see a violet color from the optic fiber.

Although the side emitting optic fiber is more robust than El-Wire, I have found that it can break if it is bent several times in colder weather. On clothing, this can be a problem in knees and sleeves, especially if it is sewn inside seams. I will discuss this issue and how to mitigate it later on in this paper.

The method that I use to install side emitting optic fiber is discussed in detail, followed by some detail on the home brew lighting system on my bicycle.
LED / Fiber Optic Assembly

The following diagram shows an overview of the LED / optic fiber assembly.

To assemble the LED / fiber optic assemblies, you will need a combination of electrical and mechanical tools. The following is an overall view of my work area:
Among the tools that you will need are a voltmeter, adjustable power supply, vice, hacksaw, file, screwdrivers, pliers, wire cutters/strippers, and a clean surface to mix your epoxy.

The first thing you need to do is to prepare the LED and its heat sink. You start with the LED itself, which looks something like:

Please note the hole around the edges of the LED's. Those are for the mounting screws. The silver pads are the soldering pads for the electrical wires. The globe (or dome) in the center is the emitter; ie; where the light is emitted from the LED.

The LED's require heat sinks to draw heat away from the light emitter. I use copper plates that I cut from a 1/8\textsuperscript{th} inch thick; 1 inch wide copper bar.\footnote{Available from either Metals Supermarket (if you have one in your area) or www.onlinemetals.com}

Using a vice and hacksaw, I cut a piece off of the copper bar that's about 1 to 1 and 1/8\textsuperscript{th} inch long:
Once the copper heat sinks are cut, they need to be marked and drilled in order that the LED’s can be mounted on them using screws and nuts. First mark the copper plates as shown, using a marker pen and the LED assemblies as guides.

Next, you need to drill the heat sinks.

Choose a drill that is suitable for your screw size. I have been using size 4x40 screws. For these, I use either a 7/64\textsuperscript{th} /8\textsuperscript{th} inch drill bit. It is best to use either a high speed steel or cobalt drill bit:
Once the copper plates are drilled, you will need to file them with the file to remove sharp edges. This is especially important if you plan to use the assemblies in a clear plastic raincoat or other clothing. The filed copper plates are shown below:

Next, you need to solder the leads onto the electrical solder points on the LED's and then test the LED's to make sure they are working. This must be done prior to any further assembly because you will be applying epoxy to the LED's base plate, which can interfere with your soldering.

To make this part of the job easy, I use what is called a 'third hand double clamp'. It consists of a stand with alligator clips.5

I use 2 third hand's. One for each lead; placing them on either side of the LED. The following photo shows my arrangement as I am about to solder the leads.

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5 Third Hand with Base; available at Rosenthall Jewelers Supply at (http://www.rjsintl.com/productListing.asp?category=Soldering&cat1=Tools&cat2=Double+Third+Hand)
Once you solder the leads, you need to identify which lead is connected to the positive (+) terminal of your LED’s. This is important. LED’s, unlike normal incandescent light bulbs, are polarized. What I do is to tie a loose knot on the wire that’s connected to the positive terminal, as shown:

After soldering your leads, it is a good idea to connect your LED’s to your adjustable power supply and test them. This will ensure that all of your connections are okay and that you have correctly identified (and marked) your positive (+) lead.

Please note that LED’s are current sensitive and that you must use a current limiting resistor in series with your LED’s. My complete setup, with my LED’s lit is shown:

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6 Detail information on LED’s and resistors is at http://led.linear1.org/why-do-i-need-a-resistor-with-an-led/
Please note that these LED's normally take about 360 milliamperes of current for normal operation. To work with them, you should not power them with that much current; they would be too bright to look at. In my photo, they are running with about 100 milliampere.

Once you have tested your LED's, your next step is to glue the PVC tubing to the LED's. The PVC tubing is used to contain the epoxy that will be used to firmly hold the end of the optic fiber to the light emitting part of the LED.

For this step, as well as mounting the optic fiber later, you will need a clear epoxy. The epoxy that I use is called System 330. It is from Wayzata. It is available from most jewelry supply companies.\(^7\)

System 330 epoxy is a binary epoxy. You will get two containers, each with one component. You need to apply equal amounts of each part to a clean surface. I use a sheet of stainless steel. Once you have equal amounts of each part, you then need to mix the parts together. I use an old screwdriver or knife for this purpose. The more thorough you mix the parts, the clearer and stronger your epoxy will be.

Please note that once you have mixed the two parts, you will have approximately ½ hour to apply the glue before it starts setting.

Now that you have mixed the epoxy, you will need to apply it to the surface of the LED assembly. Here, you will need to be careful not to apply the glue to the emitter itself (the clear dome piece in the center of the LED assembly, but on the plate around it.

\(^7\) In the Portland, Oregon area, it's available at West Coast Findings, 534 SW 3rd Ave, 6th floor
Once you have applied the glue to the surface of the LED assembly, you will need to cut a ¾ inch piece of the 3/8th inch PVC tubing as shown below:

After cutting your PVC 'barrels', you need to put them on the LED's as shown below:

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8 3/8th inch PVC tubing is available at most hardware stores. I got mine from ACE Hardware at 36th and Division in Portland, Oregon.
You need to ensure that the PVC is in contact with epoxy at all points on the LED assembly's surface around the LED's emitter (the clear dome in the center). Now, you need to let the epoxy set for about 2 hours before proceeding any further.

While the epoxy is setting in your LED assemblies, you can prepare the side emitting optic fiber. First, you need to cut it to the desired length. This can be done with either a knife or a pair of scissors.

Once the epoxy holding the PVC 'barrels' is set, you can now mount the LED's onto the copper heat sinks:
The next steps; attaching the optic fiber to the LED assemblies, can be performed easier if you can insert the LED assemblies into a jig that can hold them steady. Because of the nuts protruding from the underside of the heat sinks, you will not be able to lay the assemblies flat on your workbench. What I use are two metal bars, which I lay on my workbench to form a 'rail' assembly such that the nuts can extend between the bars and the LED assemblies lay on top as shown below:

At this point, you will need to once again connect your LED's to your power supply and current limiting resistor. You will need to have the LED's lit (energized) to perform the next steps.

Once you have your LED's lit, and secure in your holding jig, your next step is to insert your optical fiber into the alligator clips of your 3rd hand clamps. You should use one 3rd hand for each of your LED assemblies you are making:
Adjust your 3rd hand clamps so that the end of the fiber rests snugly on top of the LED's emitter as shown:
Next, you need to gently and carefully move the fibers out of the PVC 'barrels'. You must handle the 3rd hand clamps by their bases for this step as shown. It is important not to change the settings of the 3rd hand clamps themselves.

Next, you need to fill the PVC 'barrels' with epoxy (mixed as discussed earlier):
Now that your PVC 'barrels' are full, you need to insert the optical fiber into the epoxy as shown:

As you insert the fiber into the PVC 'barrels', you will need to align the end of the optic fiber so that it rests on top of the LED's emitter (the clear dome).

You will find that it is very difficult to see exactly where the LED's emitter is because of the air bubbles in the epoxy.

This is where it is important to have the LED's lit. You can observe the amount of light that is entering the optical fiber from the LED by looking into the other end of the optical fiber. Gently move the fiber around against the LED's emitter by grasping the base of the 3rd hand clamp while observing the opposite end of the fiber as shown:
You are done with the assembly. It is very important not to disturb anything as the epoxy sets. You should leave the LED's powered on while the glue sets and keep an eye on the amount of light going into the fiber, especially during the first hour or so that the glue sets. I have had the fiber shift on one of the LED's during the time the glue is setting, requiring me to gently move it back to where it is supposed to be on top of the LED's emitter.

It is best to let your epoxy set for at least 10 to 12 hours. You can help the setting by placing a lamp over your LED assemblies.

An optional step, performed after the epoxy is set, it to wrap the LED assemblies in either black electrical tape or duct tape so that the bright light from the LED itself does not detract from the dimmer glow from the fiber.

At this point, your LED assemblies are ready to be installed, either in clothing, on your bicycle, or other piece of art.
Bicycle Lighting System

My bicycle lighting system consists of El-Wire, LED's and optic fiber, high intensity discharge (HID) lights, as well as high power LED's for the red tail lights.

This system is entirely home brew. I have had poor luck with store bought HID kits, where one kit blew out within 1 month and it's warranty replacement blew out about 1 year later.
There are two HID lights. One is 10 watts and the other is 30 watts. They are mounted on a bracket that welded together from stainless steel tableware from a thrift store.

The tail light consists of two 1 watt Luxeon Star high intensity Red LED's with built in optics. They are fastened to the seat post using heavy clear PVC that was melted together using a heat gun:
The El-Wire (which is used for the main frame as well as the rear pannier rack) and the side emitting optical fiber (used for the handlebars, the fenders, and the front pannier rack) are fastened to the bike using flexible clear PVC strips which are melted together using a heat gun. You could use tie wraps for this purpose.

The one tricky part of mounting the optic fiber is mounting it onto the fenders. For this, I used an aquarium silicone sealant, found in most hardware or aquarium shops.

Powering everything is a 10 amp hour 12 volt NIMH battery. This is in a home made pouch that hangs from the top tube of the frame:

The costs for this system are as follows:

1. The two front HID light (30 watt and 10 watt) – about $300.00
2. The LED's for the tail light - about $15.00
3. The 10 amp hour 12 volt battery – about $50.00
4. The El-Wire – about $30.00
5. The side emitting optic fiber – about $30.00
6. The colored high power LED's driving the optic fiber – about 50.00
7. Misc parts – about $10.00

Total, about $475 and a lot of really fun, educational work!
Tips on Lighted Raincoats

Here are some tips if you want to make lighted raincoats like the ones that I have.

First of all, to work with clear vinyl, you really need an industrial sewing machine with a full walking foot:

This is a Sunstar LTD machine that will set you back about $1500.00 new. You really should have this machine in a decent work area:
As you make your garment, you need to make sure the seams in which you want your optical fiber be at least one inch wide:

When you sew on hems, sleeve ends, or other components that cross your seams in which you plan to insert optic fibers, you need to ensure that you do not sew through those seams, but to bridge over them by doing:

1. Sew up to the edge of the seam.
2. Sew backwards to secure the stitch
3. Lift the sewing machine foot
4. Manually pull the piece so that the sewing machine's foot is on the other side of the seam
5. Sew forward a few inches
6. Sew backwards to secure the end of the stitch
7. Proceed with your sewing

You should have something that looks like:
It is best to sew your entire garment prior to inserting the LED assemblies. This way, you will avoid having to work the LED assemblies under your sewing machine, which can be a challenge.

When you are ready to insert your assemblies, arrange your garment so that the seams are open on top; ie; where you bridged the seams would be on top. The following picture should help:

Cut a one inch wide, about 6 to 8 inch long plastic strip (from the same plastic that is used on the garment. Lay this strip so that the end of the strip is about 1/8\textsuperscript{th} inch from the opening in the end of the seam. Glue with a glue called Instant Vinyl.\footnote{Instant Vinyl is used for repairing vinyl clothes and toys. It is available in most fabric stores. In Portland, Oregon, you can get it at Mill End Fabric Store on Millport Ave in Millwalkie, Oregon.} Apply the glue only from the end of the strip to about 1 inch from the end, as shown:
Wait about 2 hours for the glue to dry. Then insert the optic fiber into the seams as shown below:
After you have inserted your fiber assemblies, you are ready to secure them with the plastic strips.

Fold the strips up and over the LED assemblies and then glue as shown:

Next, wire and test your LED's:
Once you are satisfied that all of your LED's are wired and operational, you are ready to fold up and secure the hem.

At this point, if you desire, you can add low voltage LED Christmas lights (likes the ones you see in the photos of my own garments). You can add these into the hem.

When all is done, you fold up and glue the hem to the garment as shown:

Expect to spend about $4.00 per lineal foot of optic fiber (average for both fiber and LED's based on the average length of seams in my garment)

Expect to spend about an average of one hour total time for each LED/Optic fiber assembly.

Expect a lot of learning and mistakes.

Don't expect anything from any stores. Nothing like these are available anywhere! We are totally on our own!