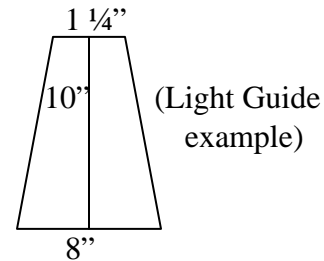# Building Scintillator Detectors
By: Jennifer Tighe

Materials: Parts
- 4 photo multiplier tubes (PMT) (Type: Hamamatsu 931A)
- 4 PMT Bases (Hamamatsu; HV Power Base; Regulated Output; HC 122-01)
- PMT Mount
- Power supply
- 4 light guides (trapezoid shape)
- (1" thick and 1 ¼" end is tapered to 5/8" thick)
- 4 pieces of Scintillator Plastic (30" x 8" x 1")

1 ¼"

10" (Light Guide example)

8"

   *You can get the pieces of acrylic plastic, for the light guides, cut to shape and polished (not yet tapered) by ordering them from TAP Plastics at 1(650) 962-8430.

Materials: Sanding, Polishing and Assembly
- Vise
- File
- Sandpaper-Emery grades 220, 320, 400, 600
- Tub
- Glue: Acrylic Cement
- Gloves
- Soft Towel
- Polish: Plastic Scratch Remover Plus 210
- Optional: Buffer

Procedure:

-Cutting

   You want to have everything cut to shape before you begin any filing or polishing. It is best if all the surfaces are flat and transparent. Hopefully most of your materials will be pre-cut and polished as this will cut down the amount of work you will need to do. If you do need to cut the plastic, it's best to have an adult use a band saw to cut it for you.

-Filing

   (Note: File only if the plastic is really rough.) Put the scintillator in a vise to get a flat surface where you want to file. If the plastic isn't covered by anything (ex. Aluminum sheet), then you should wrap it with a towel so that the vise doesn't scratch it. One problem we had when filing the scintillator was, if you file too fast, it will produce too much heat and the scintillator will start to melt. If this happens, slow down and wait for it to cool then continue to

file slowly. Filing the light guide is a lot easier than the scintillator. This is because it doesn't melt as easily. Go through the same step to file the light guide as you did the scintillator plastic.

-Sanding

As with the filing, you should have the scintillator or the light guide plastic in a vise, so that you can have straight sides. Everything that was filed will also need to be sanded. When sanding, you need to sand in one direction with one type of grade. When you change grades, sand in the opposite direction that you sanded previously. After you finish sanding with the finer grade, you shouldn't see any scratches from the previous grades. Start with the coarser grades and work your way up to the finer ones. Begin with 220, then 320, 400, and lastly 600 grades emery sandpaper (Note: all of the fine sanding for the light guide and the scintillator plastic is best done in a medium sized tub of water to prevent crazing). If sanding is done well, polishing won't take very long.

Photo Multiplier Tube Mount

Only the flat part of the PMT Mount needs to be sanded. It should be sanded the same way as the light guide and the scintillator plastic was, but it doesn't have to be done wet. The flat side that was cut cannot be rounded at all. It needs to be perfectly flat. Also, you need to polish it flawlessly because this is where the signal goes through to get picked up by the PMT. It is helpful to use the buffer for final polishing. Make sure to store it safely so that it doesn't get scratched.

Piece of plastic tubing cut so that the PMTs fit inside. The side that is glued onto the light guide should be flat. This is also the side that the sensor of the PMT will face.

-Polishing

I found that "Plastic Scratch Remover Plus 210" polish works best. A soft, clean cloth is necessary for polishing by hand. Gloves are needed for polishing, to prevent fingerprints from getting on the plastic. For simple polishing, I polished a little bit by hand and then I went over the surface with a buffer to make it perfect. After polishing, one should clean the surface thoroughly. Leftover polish makes it hard to glue and it's more likely not to hold very well.

-Gluing

Gluing is one of the more difficult and critical part of building scintillator detectors. You want to try to keep the glue off of the plastics as much as possible. When we glued our light guide onto the scintillator, there was already aluminum sheet covering the scintillator. Try to cover as much of the plastic as you can. If you order the light guides from TAP Plastics there should be a plastic of some sort covering the large sides of the light guide. I suggest you leave those on; it will prevent the surface from getting damaged.

To prepare the gluing, put the scintillator in a vise. It helps a lot to have a drop sheet that can be taped to the scintillator. Use tape with the least strength adhesive to prevent the adhesive from remaining on the scintillator after it has been removed. After everything is covered as best as you can, make sure the light guide properly lines up with the scintillator. Once you do that you can plan how you're going to glue it. Acrylic cement should be used for gluing. It helps to spread a lot of glue everywhere on the edge of the scintillator plastic. Then, roll the light guide onto the scintillator while pressing down very hard. You want to have the least amount of bubbles in the joint. Some are okay, but it's best to try to get the most out as possible. If you have to take the light guide off to reposition it, put on more glue. Let the joints set overnight.

The next day you're ready to glue the PMT Mounts on. You can use the same glue that you used on the scintillator and light guide joint or you can use 5-min epoxy. I recommend using the acrylic cement because we had some mounts break off when using the epoxy. The same concept goes into gluing the mounts on as the scintillators. It's a lot easier to get all the bubbles out of this joint and it's more important. It should be transparent even before the glue dries. This joint should set in an hour. One critical thing to remember when gluing on the PMT mount is, to think about how far over it needs to be on the light guide so that the sensor of the PMT will fit where it needs to be.

-Wrapping The Detector

First, cut the aluminum sheet to the size of the scintillator detector. If you're using aluminum foil, wrap the foil around the detector trying not to crease the foil or overlap it. When using the aluminum sheet, make sure that you leave enough room to cover the bottom. It's easiest to fold the aluminum around the bottom first and then pull the sides in towards each other. You want to make it as tight as possible. Tape the aluminum together down the seam. It's best to use a couple pieces of tape on the middle crease. Next, tape the bottom. You want to make it tight and prevent any seams in both the aluminum and the electrical tape. After the bottom is sealed, then I would suggest taping the light guide next. Although, there will be some creases on corners of the aluminum.

Cutting The Aluminum
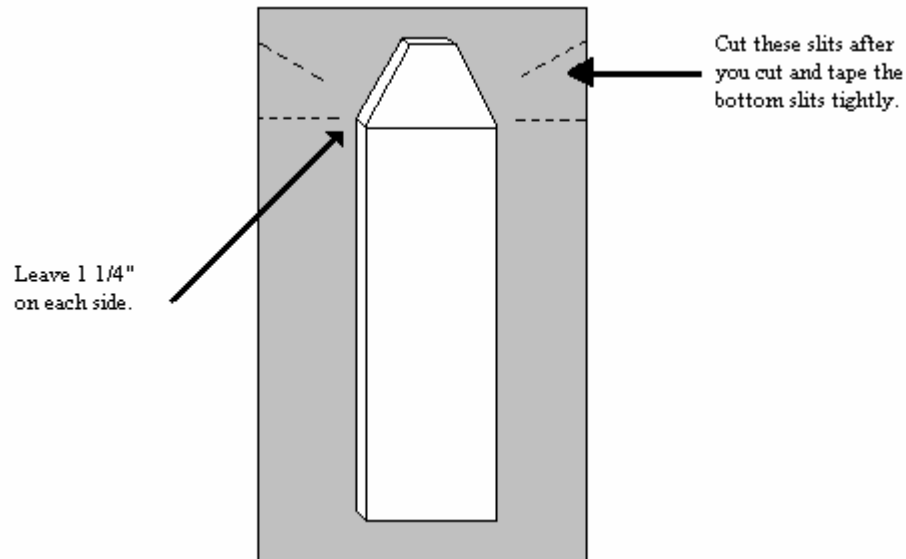
Note: Before you cut the aluminum where the light guide is, the aluminum will have been wrapped around the sides and the bottom of the detector. You will still be able to cut it the way you need to.

Tape all around the seams to make sure that no light will be able to escape. You don't want the electrical tape or the aluminum to crease because that increases the likelihood of light leaks (again, the aluminum will have to be creased some, but try to prevent it). Before you start to wrap the PMT with electrical tape, you will need to cut a piece of aluminum that will cover any spots where you can see the light guide. Also, cut a piece that will go over and around the PMT. Next is the hardest part of the wrapping; you need to tape around the PMT. This is the most likely spot for light leaks. It's best to use short pieces of tape and go in all different directions. This is the most important spot to make sure that nothing creases. You might want to put a small piece of wood about 2" x 1" x 1" underneath and on either side of the PMT mount to make it more sturdy. This part is optional, but I think that it's a good idea. If you're using the aluminum sheet, you don't need to cover the whole scintillator detector. If you're using the aluminum foil, then you might want to use cardboard or poster board to make the detector more durable. Also, if you're using the foil, you will need to cover the whole detector with electrical tape to make sure that there are no light leaks.

-Testing and Fixing Light Leaks

To test for light leaks, you will need thick, dark cloth that is able to thoroughly cover one of the scintillator detectors. After the scintillator is covered you can hook it up to the power supply. Also set up the detector to an oscilloscope. Make sure that the detector gives a good

reading while it's covered. See **Figure 1** for a normal reading. Once you have a good reading, you're ready to test for light leaks. Start with uncovering one end and work you're way to the other. If you see a reading on the oscilloscope that suddenly drops and there is no more curve on the screen immediately cover the detector and detach it from the power supply. This is the indication of a light leak. Uncover the detector and tape the place that had the light leak. Retest until the light leak does not occur again.

Figure 1
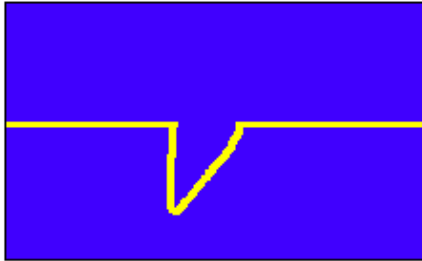
Normal Oscilloscope Reading: The graph should be going from the curved position to just a straight line continuously.

-Acknowledgements

Thanks to SLAC for the Scintillator Detectors. Thanks to TAP Plastics for cutting and polishing the light guides for us.

Finished Scintillator Detector

Note: If you're using aluminum foil, the whole thing must be covered in electrical tape.