Development of the Tagger Microscope

(Prototype for the Gluonic Excitation Experiment)

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Abstract

As a result of the dynamic nature of the design and development process, it is often difficult to quantify results or progress. In this paper I attempt to explain the process and considerations behind the development of the tagger microscope prototype for the Gluonic Excitation Experiment. The four main components of the microscope (parallel railing system, fiber bundles, electronics, and housing structure) are comprehensively discussed in this paper, as are both the successes and failures of the project. In addition, a large section of this paper is devoted solely to the discussion of the procurement, processing, and mounting of scintillating and waveguide fibers. A brief discussion is given concerning the three different approaches (ion implantation, laser ablation, and chemically assisted mechanical polishing) that are being considered for the fabrication of the 20 micron thick diamond radiator. Future considerations and trials necessary for the successful completion of the tagger microscope portion of the GlueX project are also discussed.

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Introduction

The Gluonic Excitation Experiment (GlueX) is intended to help in the exploration of the confinement of quarks and gluons inside the hadron. The ultimate objective of the experiment is to provide much needed data to assist the quantitative understanding of the confinement of quarks and gluons in quantum chromodynamics (QCD). QCD is a quantum field theory of the strong interactions (color force) which was introduced, soon after the existence of quarks was proposed, as a way to explain the coexistence of quarks at identical quantum states inside the hadron without violation of the Pauli Exclusion Principle. QCD is an important part of the Standard Model of Particle Physics. Confinement, formally known as Color Confinement, is the phenomenon that color charged particles cannot be isolated singularly and therefore cannot be observed directly. Analytic proof does not currently exist to shows that QCD should be confining. One hypothesis is that confinement, a unique property of QCD, is due to gluons (force carriers) having color charge. Therefore, as two quarks are separated narrow tubes (strings) are formed by the gluon field which brings the quarks back together. Due to this occurrence the color force that hold them together, which is large between quarks, remain constant regardless of distance. Understanding the soft gluonic field responsible for binding quarks in hadrons is required in order to understand confinement.

The GlueX experiment will generate a linearly polarized photon beam using coherent bremsstrahlung produced by sending a high energy electron beam from the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility through a diamond crystal. The diamond crystal and electron beam are orientated so that the electrons travel nearly parallel to the planes of the atoms in the crystal, which produce photons that are polarized in the direction perpendicular to the plane of the atoms. The photon (electromagnetic radiation) production occurs by bremsstrahlung produced from a high energy electron deflected (acceleration of a charged particle) in the electric field of an atomic nucleus. The photons and deflected electrons pass through magnetic fields produced by a quadrupole magnet and a dipole magnet, called the tagger spectrometer. Since the photons have no charge they

continue on unaffected, but the charge of the electrons cause them to deflect in the magnetic fields. The amount of deflection that occurs is based on the magnitude of the electron's energy and therefore provides a way to measure its energy by measuring its deflection using the tagger microscope. The tagger microscope is to be placed on the parallel-to-point focal plane and centered at the vertical plane of the electron beam. The microscope measures the electron's location based on its interaction with scintillating fiber (SciFi) detectors within the microscope. The interaction of a charged particle with the scintillators result in the production of light which is measured through the microscopes electronics. Since "tagging" is a statistically meaningful event, the signal is time stamped which helps to later correlate an electron to its photon counterpart that produced an excited meson within the target, thus a "tag" is placed on the photon of interest. In this way, "accidental tags" can be dealt with by statistical methods. The GlueX experiment has the ability to produce mesons (subatomic particle composed of one quark and one antiquark) by using gamma rays (photons) to excite the target, a hydrogen nucleus. Photoproduction is expected to be particularly effective in producing exotic hybrid mesons (mesons having internal gluon excitation), which provide the ideal laboratory for testing QCD in the confinement regime since these mesons explicitly manifest the gluonic degrees of freedom. A hermetic solenoid-based detector is used for collection of data on meson production and decays. The statistics after the first year of operation are expected to exceed current photoproduction data by several orders of magnitude.

The subject of this paper is the conceptual and physical analysis that has occurred, to date, in the production of a prototype for the tagger microscope (see Figure 1) that will be used in the GlueX experiment.

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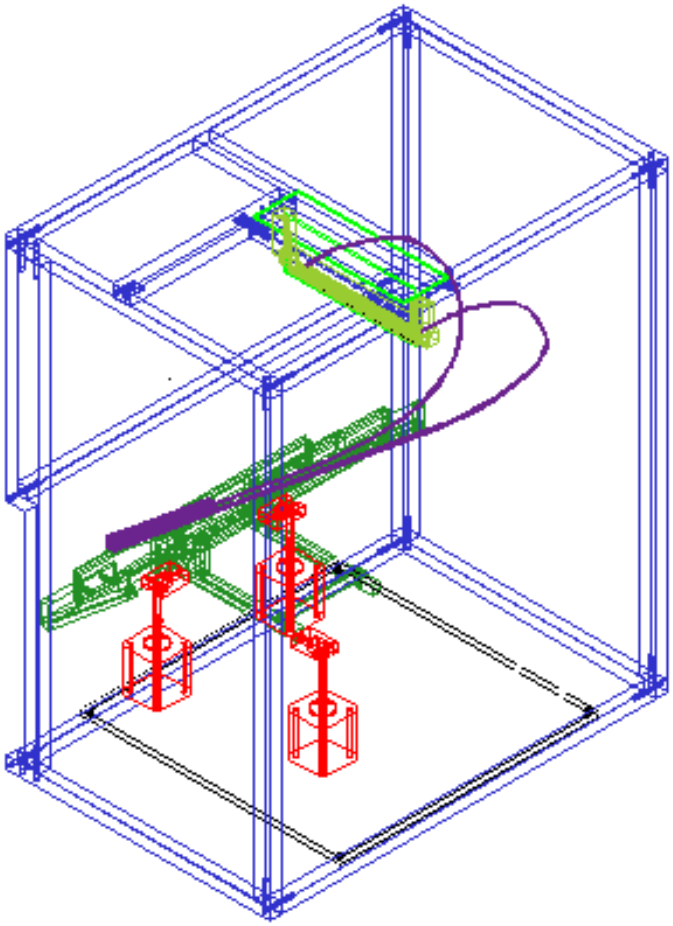

Figure 1: Tagger microscope.

Note: Only two of the twenty five fibers are shown connected to the electronic interface. This was done to simplify the rendering and clearly show the basic concept of the design.

The tagger microscope consists of four main components: parallel railing system, fiber bundles, electronics, and housing structure. The quantities of some of these components have been reduced for the prototype in order to allow us to assess the feasibility of the basic concepts and design. Completion of the prototype is scheduled for February 2010, followed by a beam-line test at Thomas Jefferson National Laboratory which will occur the following month. What follows is a detailed description of the tagger microscope (prototype) and the evolution that has taken place in its development for the GlueX project.

Development of the Tagger Microscope

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Parallel Railing System

The parallel railing system (see Figure 2) was designed for the mounting of fiber bundles and consists of: two main railings, multiple popsicle sticks, three step motors, and various support components.

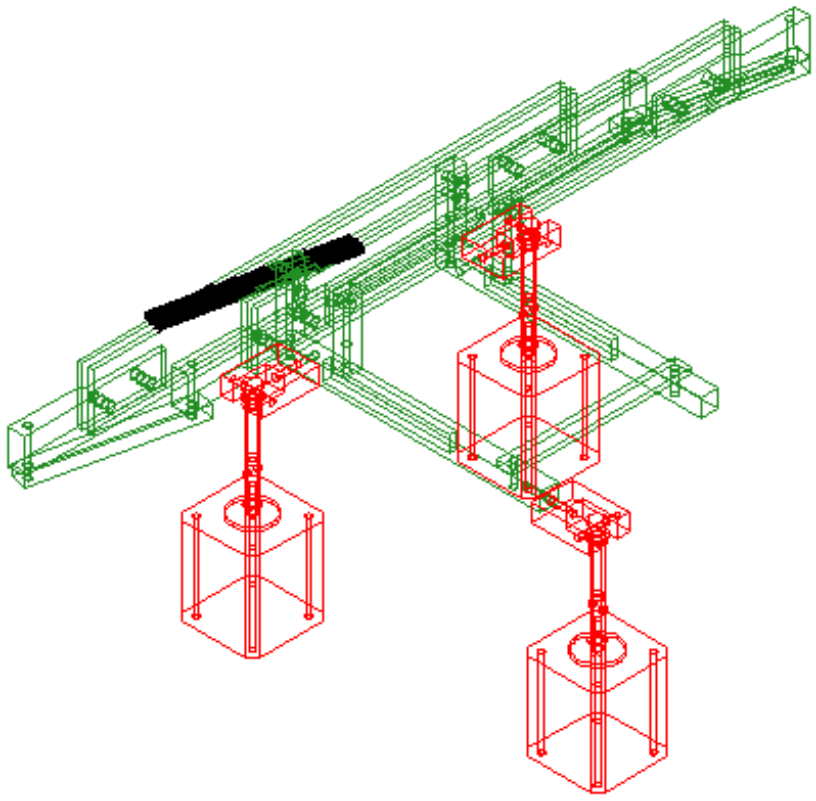

Figure 2: Parallel Railing System.
Note: Only one popsicle stick (in black) and none of the electronics are shown in this rendering.

The system has been adapted for a wide variety of fine-tuning, both manual and automatic, throughout its intended life cycle. All of the components for this system, with the exception of the step motors and required electronics, are mounted inside the main structure and completely sealed from light. The three step motors and required electronics including wiring are mounted on the underside of the main housing frame. This configuration was developed as a result of considerations pertaining to possible temperature increases inside the housing

structure. With either configuration, external or internal mounting, conduction occurs since the components are being mounted directly to the aluminum housing which essentially acts as a heat sink. Nevertheless, by placing these components on the exterior of the main structure instead of inside, we are able to limit the penetrations through the housing structure, which is light sealed, and provide a less confined heat sink, e.g. better cooling, for the power supply and electronics of the step motors. Thus the natural convection air flow, a result of heat emanating from the components, and the forced convection, due to air conditioning flow inside the beam-line building of the laboratory, accommodate greater cooling of components and helps to reduce component failures inside the sealed housing due to increased temperature levels. An additional benefit is gained by placing the motors on the underside of the housing structure since this will allow for most motor maintenance and troubleshooting to take place without disturbing both the light sealed chamber of the housing structure and other delicate components that are located within the confined space of the housing structure.

The scintillating fiber (SciFi) cross-sectional width of two millimeters (2 mm) can assist in providing discrimination between electrons created by coherent and incoherent bremsstrahlung, therefore helping to increase tagging efficiency by reducing accidental tags (see Figure 11). Accidental tags result from the counting of a signal in the tagger microscope which was not the result of an electron that was the bremsstrahlung counterpart of a photon that interacted with the target. These accidental tags can result from an electron whose photon counterpart was stopped by the collimator or just never interacted with the target; they can also result from environmental events which caused a signal in the SciFi. These environmental events can result from things such as: back splashing from the beam dump, particle showers from an electron hitting structural components, or other such events. The discriminatory capability of the fibers is exploited by having the ability to adjust their vertical location. Since the tagging efficiency is only approximately 20% for the fibers adjacent to the centrally focused fiber and about 2% for the fibers in the outer most rows, a way was needed to zero in on the focus of the beam so that the data coming from the surrounding rows could be secured, thereby lowering the amount of accidental tags that are recorded. The step motors

that have been chosen for use in the parallel railing system will allow for fine adjustments in the vertical direction (y-direction) on the order of less than 2x10^-5 of an inch (1.8 degrees per step for the motor and a thread count of 28 turns per inch). These vertical adjustments provide the capability of precisely zeroing in on one of the five SciFi rows that are going to be used. Additionally, by using three step motors in the parallel railing design it has permitted the ability to align the longitudinal axes of the SciFi parallel to the incoming electron beam, thus allowing the opportunity to maximize the light yield inside the SciFi due to an incoming electron. This increases the potential that a strong signal is registered for the event by the electronics. Improved signal strength records a larger pulse height, which is used to help with analysis of the data. Having a larger pulse height allows for easier filtering of noise and assists in dealing with the larger time walk for the leading edge discriminator, which is being used in data processing.

The five hundred (500) waveguide/scintillating fiber (W/SciFi) lengths for the full scale tagger microscope will be segregated into twenty (20) bundles (see figure 3) each containing twenty five (25) W/SciFi lengths arranged in a compact five by five (5x5) cross-sectional square (see Figure 4).

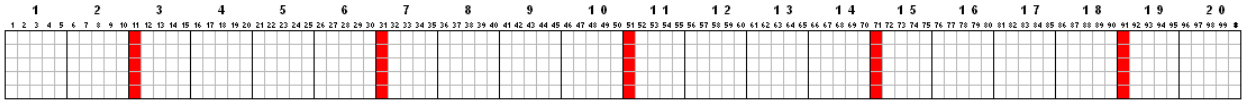

Figure 3: Channel plan for full scale tagger microscope.
Note: 20 bundles each containing 25 fibers arranged in a 5x5 square.

Development of the Tagger Microscope

(Prototype for the Gluonic Excitation Experiment)

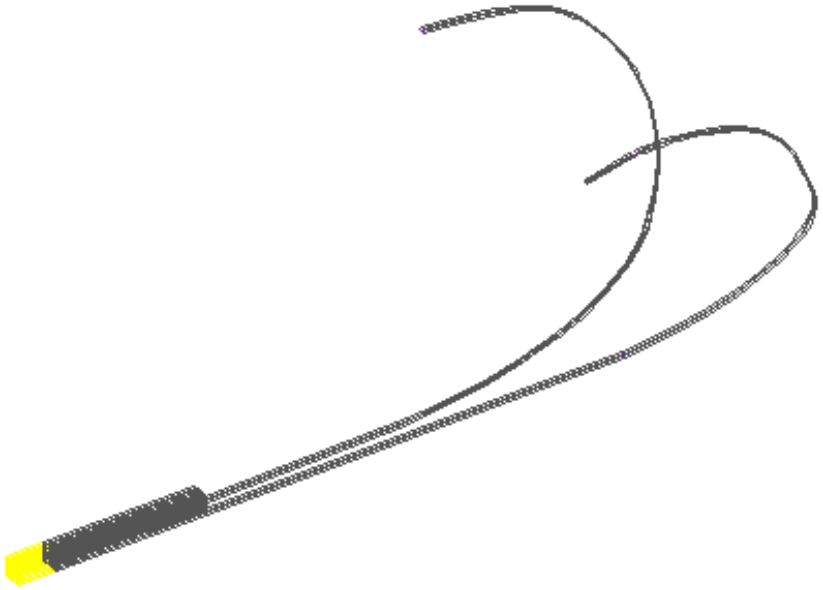

Figure 4: Bundle of scintillating fiber (yellow) and waveguide (grey).
Note: Only two waveguides are show to full length, each terminates at the chimney.

Each bundle will be glued to a single popsicle stick (see Figure 5). The design of the popsicle stick will allow for the bundle/popsicle stick combination to slide freely while the parallel railings are being adjusted (see Figure 6).

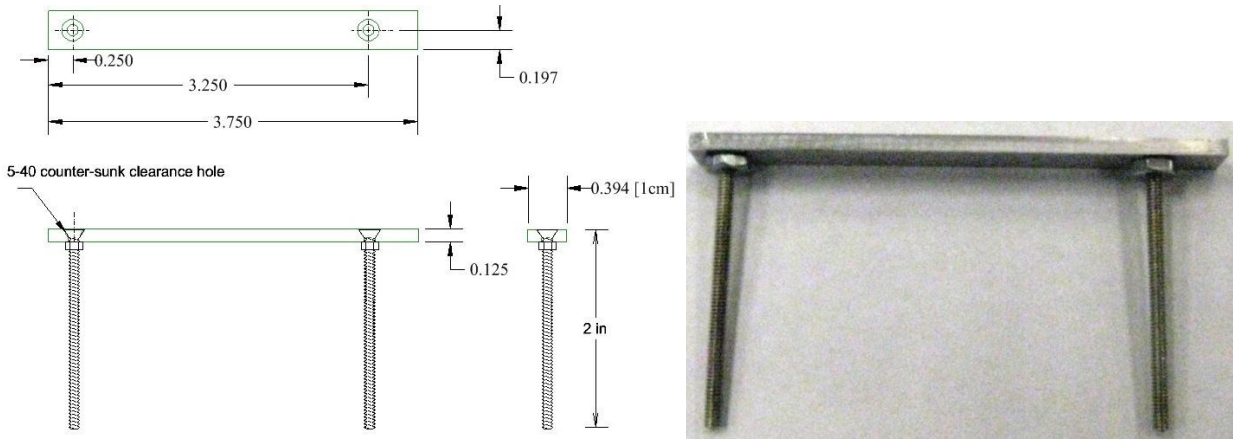

Figure 5: Popsicle Stick.
Left: Top, Side, and End Views; Dimensions in Inches unless otherwise stated
Right: Popsicle Stick Prototype

Development of the Tagger Microscope

(Prototype for the Gluonic Excitation Experiment)

Once adjustment of the railings is complete the threaded rods of the popsicle stick, which protrude through the railings, are locked into place by tightening the nut on the end of the threaded rod that is under each railing. The prototype has been designed to contain only one (1) bundle of twenty five (25) W/SciFi lengths which will be mounted on a single popsicle stick in a 5x5 square as mentioned previously.

The method of using parallel railings (see Figure 6) for mounting the popsicle sticks and thus the bundle of W/SciFi lengths was designed so as to allow for a continuous range of motion from seven (7) to ninety (90) degrees of the angle of the bundle lengths (β), with respect to the housing length (z-axis) (see Figure 7a & 7b).

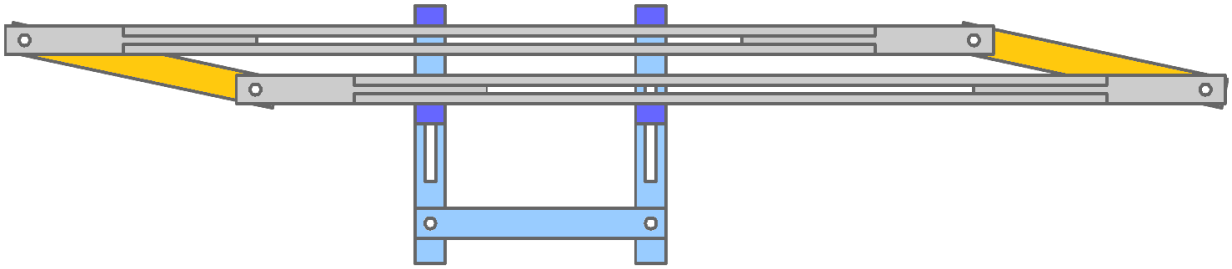

Figure 6: Parallel Railings (In Grey).

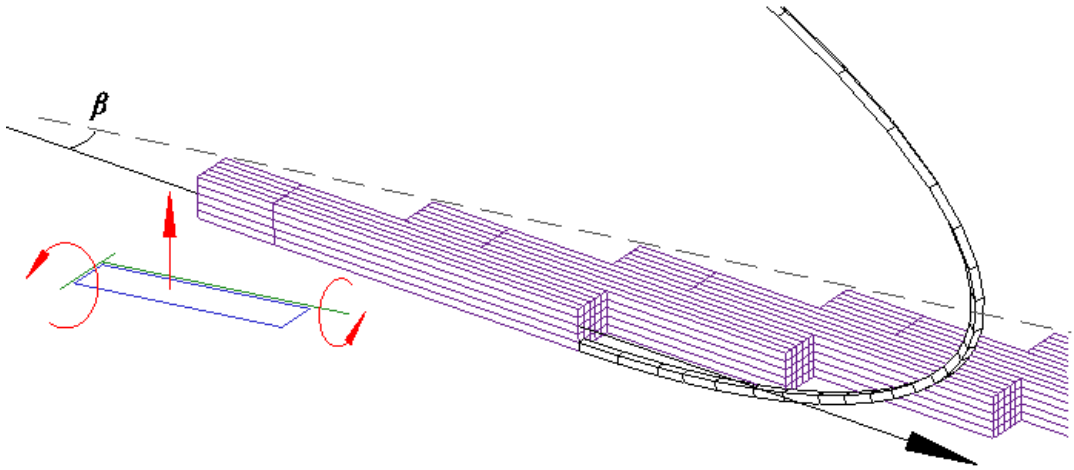

Figure 7a: Angle of Fiber Bundles (β).

Note: Has the ability to obtain any angle from 7 to 90 degrees.
The red arrows indicate the range of motion that can
be obtained via the use of the parallel railing system.

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(Prototype for the Gluonic Excitation Experiment)

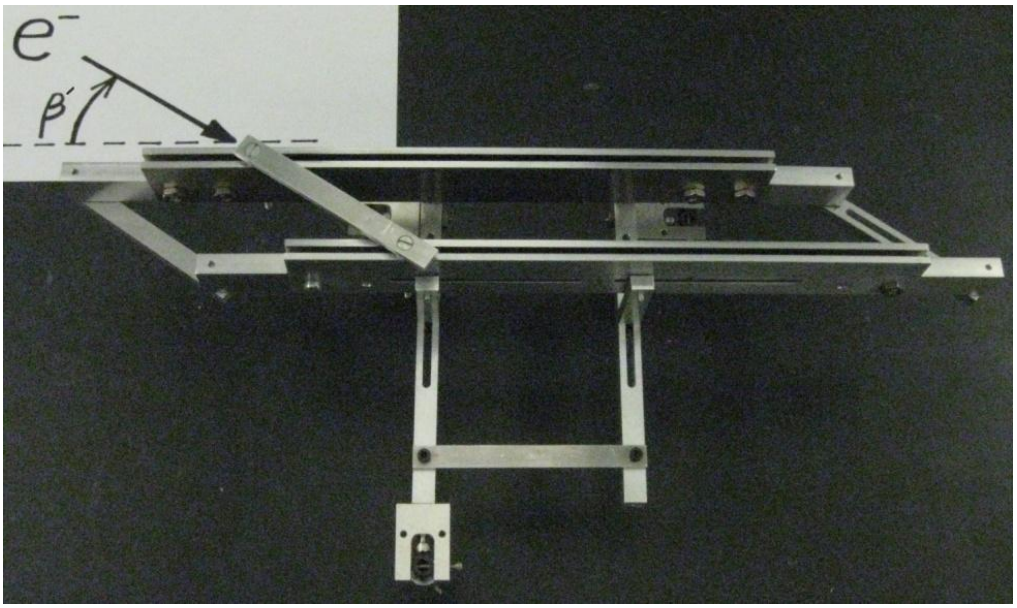

Figure 7b: Angle of Popsicle Stick (β) set equal to electron influx angle (β').
Electron (e^-) influx direction, which is parallel to the popsicle stick due to adjustment of β equal to β', is shown.

The need for the face of the bundles (i.e., end of the SciFi exposed to the incoming electron flux) to have an angle that is not parallel to the housing structure in the z-direction comes about because of the location of the horizontal parallel-to-point focal plane created as a result of the 1.5 Tesla (T) dipole tagger magnet. In order for the electron flux to enter the face of the fiber bundles perpendicular to its surface and have all twenty (20) bundles lie on the focal plane, the tagger microscope housing structure must be placed on the focal plane and consequentially angle the parallel railing system so as to produce an angle of the fiber bundles approximately seven (7) to twelve (12) degrees off the face of the housing structure (i.e., the side of the Housing Structure that will see the incoming electron flux). Unlike the remotely operated adjustments in the y-direction of the parallel railing system due to the step motors, the angular adjustment of the fibers, in the x-z direction, must be made manually while the beam line is shut down. Here we can clearly see one of the advantages of having a remotely controlled system, e.g. allowing fine-tuning adjustments while the beam line is on.

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Fiber Bundles

As stated previously, there will be five hundred (500) individual waveguide/scintillating fiber (W/SciFi) lengths (see Figure 8) used in the full scale tagger microscope.

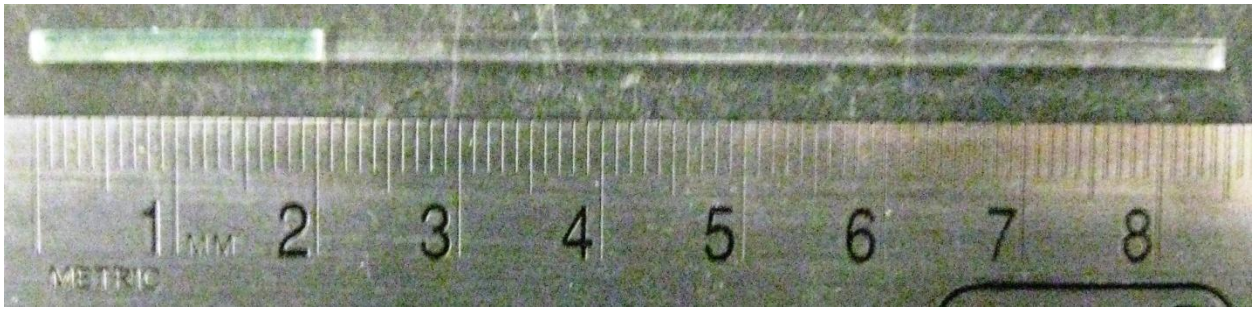

Figure 8: Photo of waveguide and scintillating fiber combination.
(Waveguide shown is not the actual length that is being used in the prototype)

These individual fiber combinations will consist of two parts: a two centimeter (2 cm) SciFi and a twenty seven inch (27 in) waveguide. These W/SciFi lengths will be segregated into twenty (20) bundles, aligned side by side in the horizontal direction, each containing twenty five (25) W/SciFi lengths arranged in a compact five by five (5x5) cross-sectional square (see Figure 3). The size and type of fibers were chosen specifically based on characteristics they could provide, which would be beneficial to our project. There are many types of SciFi and waveguides on the market; some are round while others are square, there are ones with single layer cladding and others with multilayer cladding. A square fiber with multi-layer cladding (see Figure 9) was chosen to allow for better area coverage efficiency, e.g. closer packing of fibers in a confined space.

Figure 9: End view of a waveguide fiber.
(Shows outer cladding)
Left: Unpainted fiber.
Right: Painted fiber.

Square fibers offer the ability to minimize the gaps between fibers when grouped in bundles, thus square fibers allow for parallel and perpendicular sides of the fibers to mate more cleanly than the rounded sides of circular fibers would (see Figure 10).

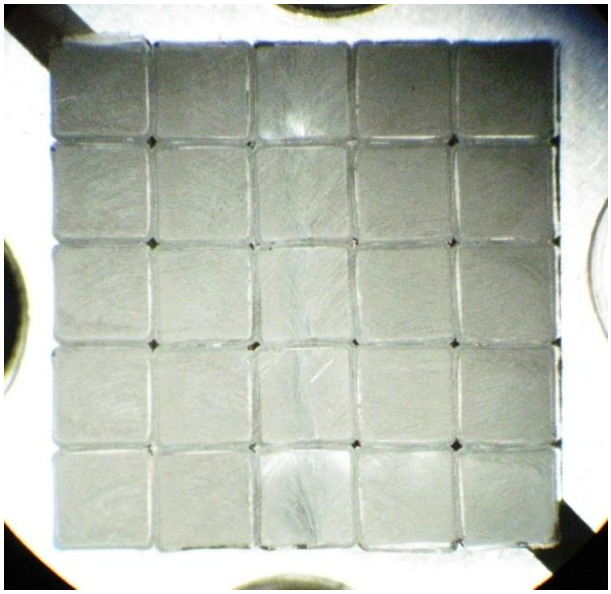

Figure 10: 5x5 Fiber bundle grouped in a compact square.
(Picture was taken directly after End-Mill cutting)
Note: Striations vertically down the center are due to a double pass of the cutting bit. The cutting bit was turning clock-wise as viewed from this picture's orientation and started from the top on the right side and from the bottom on the left side as it made each of the two passes. This allowed the bit to turn into the perimeter of the work as it was cut, therefore minimizing the possibility of flaring out the fibers on the perimeter and causing flaking of the cladding.

Thus we can minimize the loss of signal that would have occurred more readily if round fibers, of similar size, were used. The square fibers also provide effective vertical and horizontal alignment since they are easily mounted in straight vertical and horizontal lines which help to maximize the accuracy of locating the influx of electrons and thus determine the energy of the incoming electrons. The determination of the size of fibers that would be used was initially based on the capability of our electronics. A fiber cross section was needed that would correspond to a signal of up to 2 MHz based on the influx of electrons. Even though the criteria for selecting the size of the fibers were primarily based on the signal capacity of the equipment, the choice has also yielded several other benefits for the project. The selected fiber size allows the capability of using only a single row of horizontal fibers at a time to produce the most efficient output. In order to fully understand why a two millimeter (2 mm) square fiber would provide this advantage we must first discern the reason for measuring the energy of these electrons and how they were produced, which was alluded to in the introduction. The GlueX experiment starts with a twelve GigaElectronVolt (12 GeV) electron beam which is targeted at a thin twenty micron (20μm) diamond wafer. As the electron beam passes through the diamond, bremsstrahlung can occur resulting in a photon beam and lower energy electrons. The electrons and photons then pass through a quadrupole magnet which mainly adjusts the vertical focal plane of the electron beam by focusing it vertically, while the photons pass straight through unaffected. It should be noted that at the same time the electron beam is being focused in the vertical direction it is also causing slight divergence of the beam in the horizontal direction which is mitigated by the design of the poles in the magnet. Next the photon and electron beams encounter a dipole magnet; again the photon beam passes through unaffected as before, but the magnetic field causes the charged electrons to deflect based on the energy they have (e.g., a lower energy electron will bend more than one with higher energy). This is where the tagger microscope comes into play. By measuring the amount of deflection we can determine the energy of an electron. With this information and the fact that its initial energy prior to the occurrence of bremsstrahlung is known, we can calculate the energy of the counterpart photon that was emitted during bremsstrahlung and “tag” that

photon as having a specific energy. Note that not all of the photons interact with or even make it to the target; therefore a way is needed to account for these photons and disregard the measurement of the corresponding electron which was their bremsstrahlung counterpart. These signals from the tagger microscope are known as "accidental tags", which can also include signals resulting from other charged particle sources, i.e. electron dump back-splash, scatter from electrons that strike structural material, etc. This problem is minimized in several ways. Initially the photons that are a result of incoherent bremsstrahlung tend to be produced with a greater angle of deflection and do not end up continuing on to the target because they are filtered out by the first of several collimators (see Figure 11).

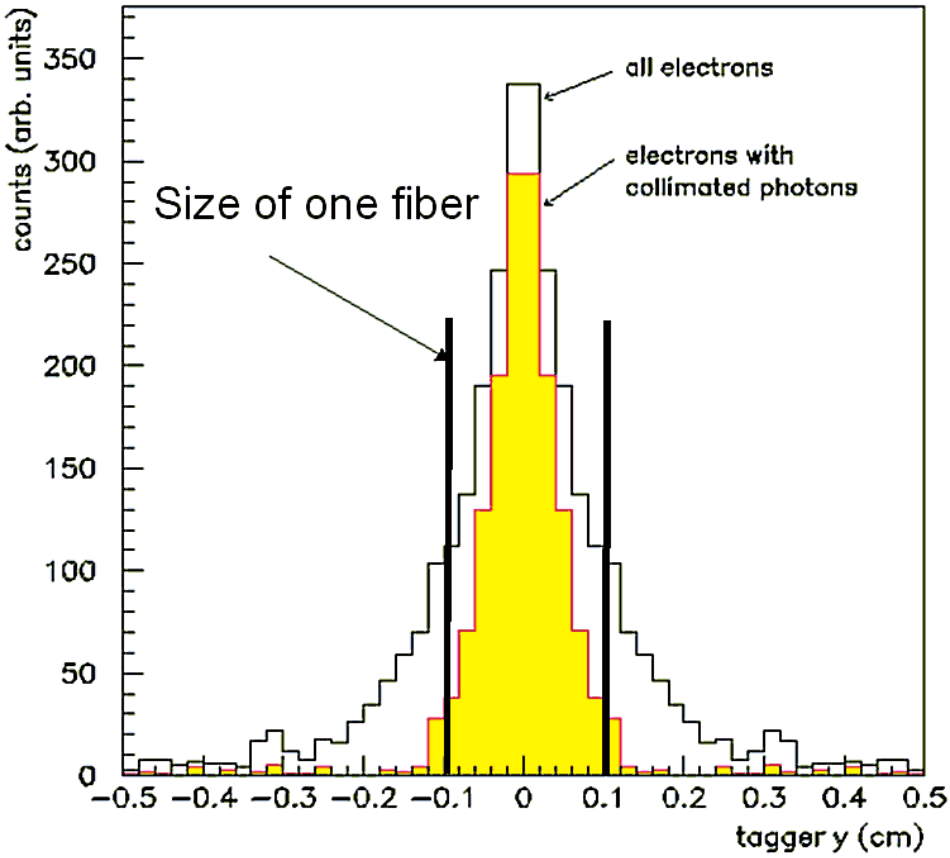

Figure 11: Effect of using the collimators.

The collimators are made of different materials and placed at set locations along the route to the target, with the first collimator having the narrowest opening and providing the polarization of the photon beam. The subsequent collimators have larger openings and have more to do with filtering out particles created further along in the beam line. To help filter out the data corresponding to an accidental tag, only one horizontal row of fibers is used at a time for data collection. Since the SciFi cross-sectional size of 2 mm allows approximately 70% of the influx of electrons with collimated photons to be counted, only one horizontal row of fibers is needed to actively collect data (see Figure 11). The method of securing fiber rows affords the opportunity to filter the data stream of some of the electrons which produced incoherent bremsstrahlung, much the same way the collimators do for the photons. Another consideration that was taken into account during the fiber selection process was the decay time of the fiber. A fiber was needed that would readout fast enough to be ready for the next electron, so as not to miss counting the next electron, but long enough to allow for reading of the signal. The rate at which we wish to process data is currently between 3 to 4 Megahertz (MHz), so by choosing a fiber with a decay time of 2.7 ns as was done by selecting the BCF-20 SciFi from Saint-Gobain Crystals, it ensured that the desired counting efficiency of 95% which lies between 3 to 4 MHz could be achieved (see Figure 12). As is detailed in the *Electronics* section further on in this paper, a way to convert the light signal produced in the SciFi to an electronic signal was achieved by the use of Silicon Photo Multipliers (SiPMs). Therefore, the selection of fibers had to consider how well it would work with the use of the SiPM. The SciFi (BCF-20) and waveguide (BCF-98) that were selected both have very high efficiency for the transmission of light at wavelengths comparable to those that corresponded with the maximum SiPM photon detector efficiency (PDE) (see Figure 13).

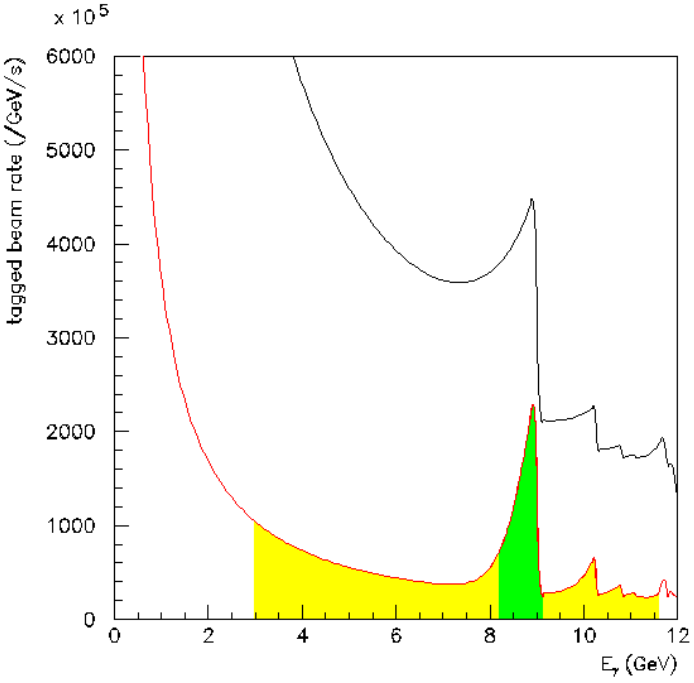

Figure 12: Tagged beam rate.

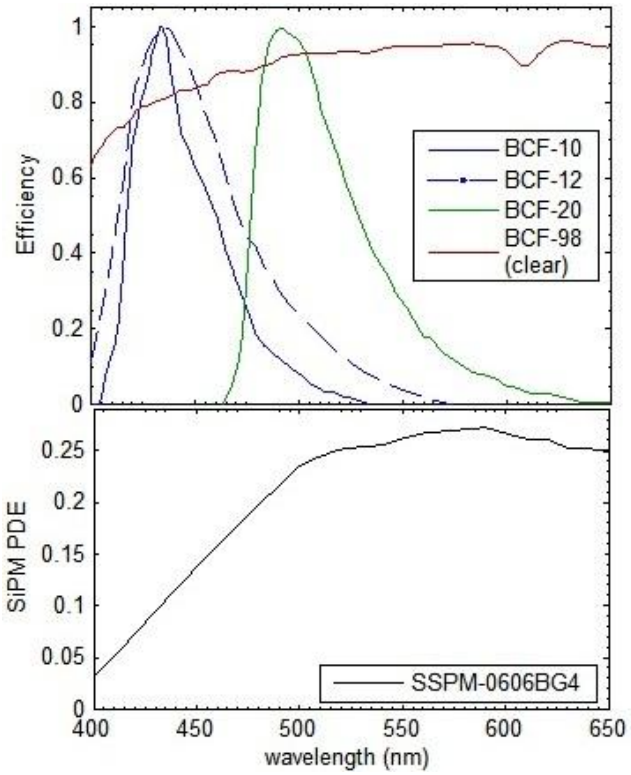

Figure 13: Supporting data for selection of BCF-20 and BCF-98.

As Figure 7 shows, the W/SciFi lengths consist of two components which must be cut, fused, and heat treated. The cutting that is required for both the waveguides and SciFi is accomplished in two steps. The two different types of fibers are received from the manufacturer on large spools measuring approximately two and a half feet in diameter. Lengths, that have been determined from TurboCad three dimensional renderings of the tagger microscope, are cut from the spools. An additional 1 cm is added to the calculated length before cutting, this ensures that any damage to the cladding due to the rough cut of the diagonal cutting tool is removed during the milling process. Once 25 fibers have been cut off the manufacturer's spool, they are grouped together and metal collar(s) (see Figure 14 and Figure 15) are placed around them to secure their positions in the bundle.

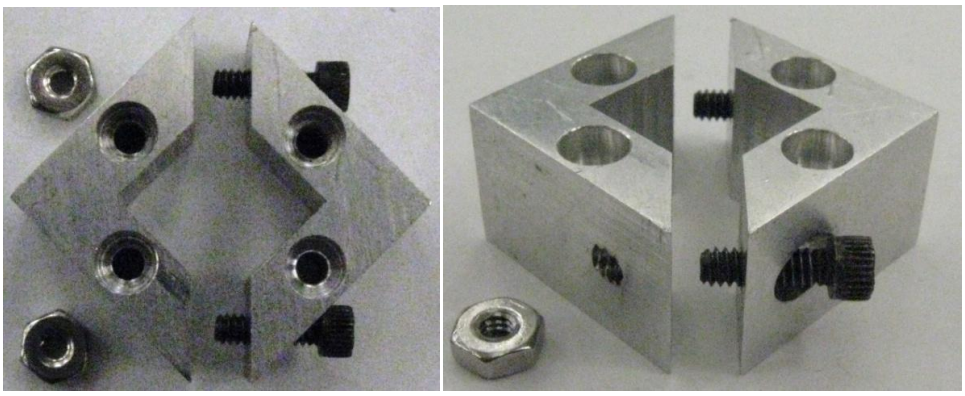

Figure 14: Metal collar used to secure a waveguide bundle.
The counter sunk holes are used to secure these smaller metal collars to a base plate to allow for mounting in the End Mill vise. The base plate and collar configuration is shown in figure 17.

Special care is taken to ensure that the fibers form a straight line once the collars are secured in place. The tendency of the fibers is to have a slight curvature to them due to the manufacture's packaging in large circular spools. It should be noted that a single metal collar is used for the SciFi bundle and is slightly larger in width (see Figure 15) than the ones used for the Waveguides (see Figure 14) and does not require the use of a base plate to allow for mounting in an End Mill vise.

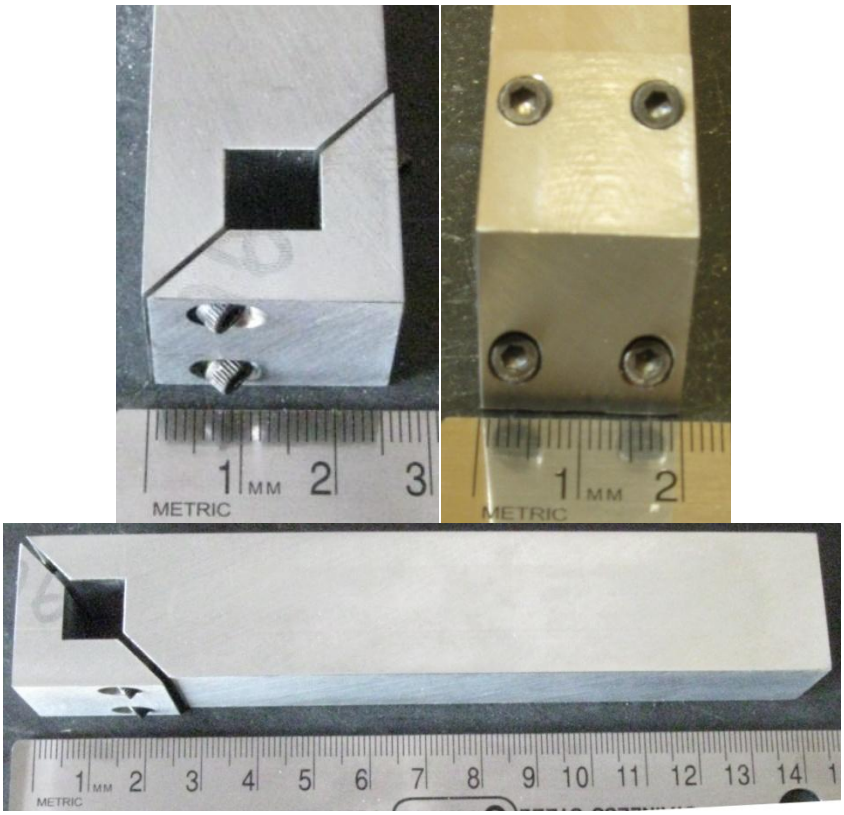

Figure 15: Metal collar used to secure scintillating fibers during milling.

The reason for the larger collar is based on the fact that the small length of the 2 cm SciFi only allows for the use of one collar. Since it has been found that milling the fibers to within less than a millimeter of the metal collar provides the maximum protection for the cladding of the fibers around the perimeter of the bundle, it was both economical and prudent to keep the current metal collars for use with the waveguide manufacturing and produce only one slightly larger version for the SciFi processing (see Figure 15).

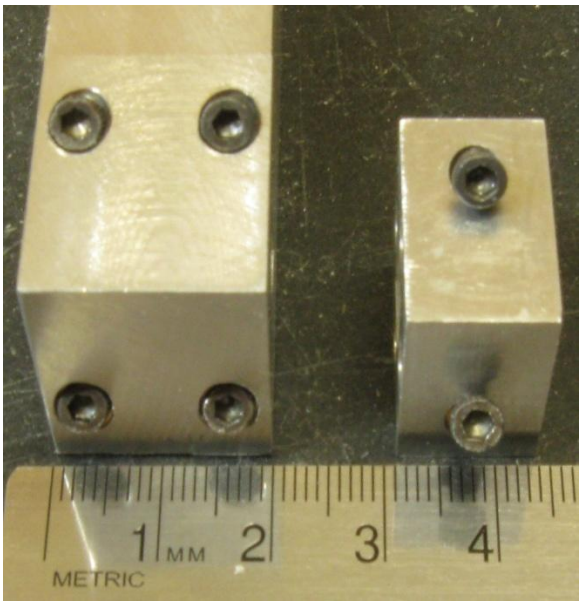

Figure 16: Comparison of two different types of metal collars.
The one used in SciFi manufacturing is on the left, while one of the several collars to secure a waveguide bundle is pictured on the right.

Thus by make a special metal collar for the SciFi bundle, which is approximately 19.5 mm wide, we have allowed the milling of the fibers down to less than a few thousandth of an inch above the collar surface on each side. This permits us to mill both sides of the fiber by simply flipping the metal collar in the End-Mill vise and therefore produce 25, 2cm, SciFi with minimal cladding damage and time. As briefly described for the SciFi, the same method of machining the fibers down to within a few thousandth of an inch of the collar surface is also done for the waveguides. The waveguides (BCF-98) that were selected for use are also manufactured by Saint-Gobain Crystals. The waveguide is a multi-clad fiber made of both Acrylic and Fluor-acrylic with a core of Polystyrene. The main difference between the SciFi bundle and waveguide bundle milling is that the waveguide bundles require multiple metal collars to secure them in place since the length of waveguide required is many times longer than the SciFi. Additionally, since the waveguide bundle is longer and the collars are smaller, a base plate is required to be attached to the collar on the end which is being milled to allow for securing the bundle in the vise of the End Mill prior to machining (see Figure 17). The End Mill (see Figure 18) is used for fiber milling by setting the bit speed to approximately 1800 revolutions per

minute (RPM) with a cradle speed dialed down to its minimum. These settings permit the maximum amount of passes of the cutting bit over the material, which allows for the cleanest and smoothest cut possible.

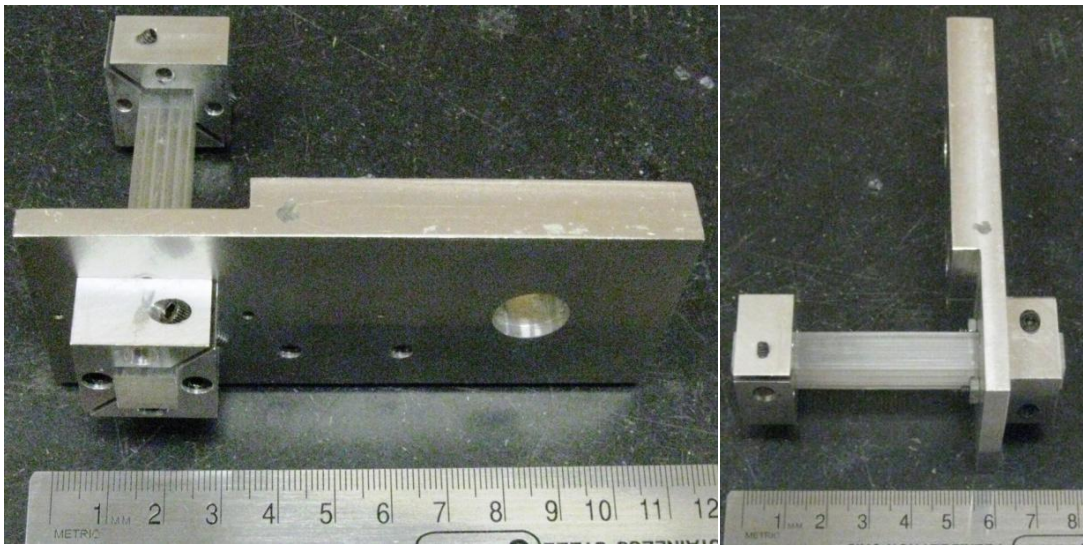

Figure 17: Base plate and collar.
(Note: The collar forms the fiber bundle into a compact square)

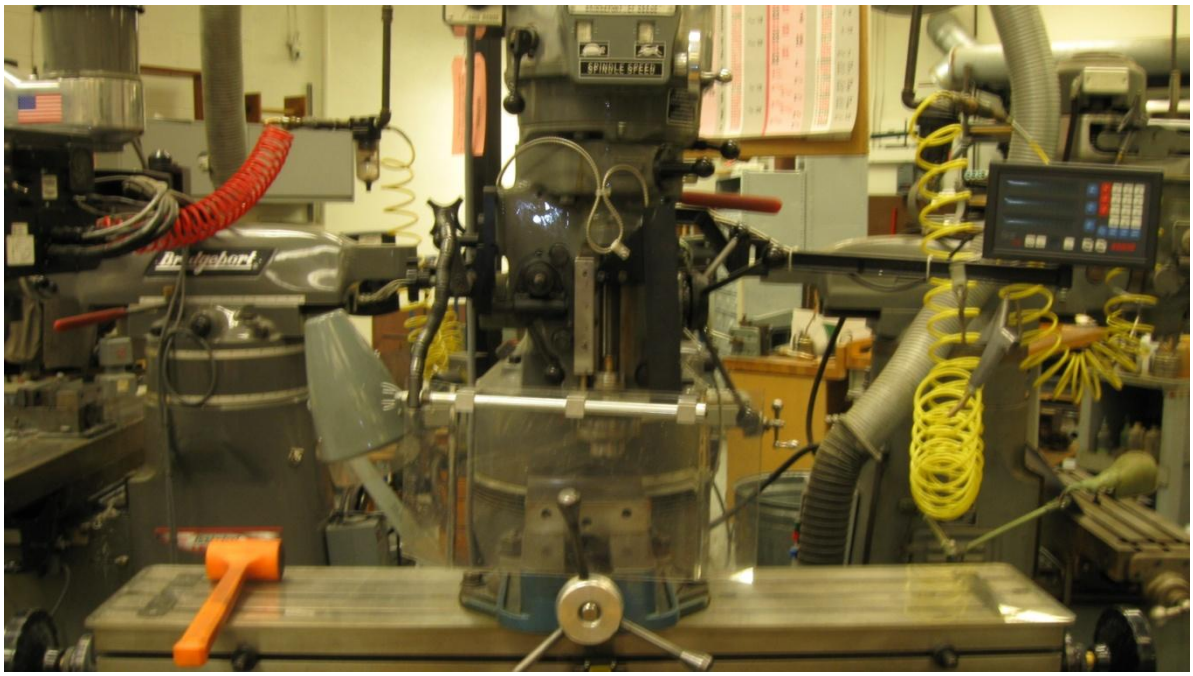

Figure 18: End Mill.

The End Mill has the ability to achieve much higher bit speeds, but numerous trials have shown that at higher speeds the vibration of the machine counters any benefits obtained by the closer passes and therefore a compromise has been found, between bit speed and machine vibration, at around 1800 RPM. In the pursuit of achieving the most efficient cut of the fibers, attempts were made to use a four fluted cutting bit in hope of a cleaner cut. The trials produced promising results for the cleanness of the surface cut, but unfortunately resulted in severe damage to the cladding on 64 % of the fibers. The basis behind this was never definitively determined, but nonetheless the use of the four fluted bit was scrapped. The testing to determine the optimal cutting procedure included consideration of not only visual inspections but also the ease of polishing the surface of the fiber ends after milling, while still in the bundle. The polishing of the fibers as a bundle, which was done using copier paper as the "grit" material, helped to determine height differences that the naked eye was unable to see. The reasoning behind this was that as the bundle of fibers were polished, we were able to see that the fibers closer to the perimeter of the bundle tended to polish more quickly for certain milling procedures while the center most fibers took much longer to show signs of polishing. Some of this was caused by the inability of the polisher's hand to hold the bundle perpendicular to the paper (see Figure 19), but it was also determine that some of the uneven polishing resulted from the fibers being pushed away at the bundle perimeter during milling.

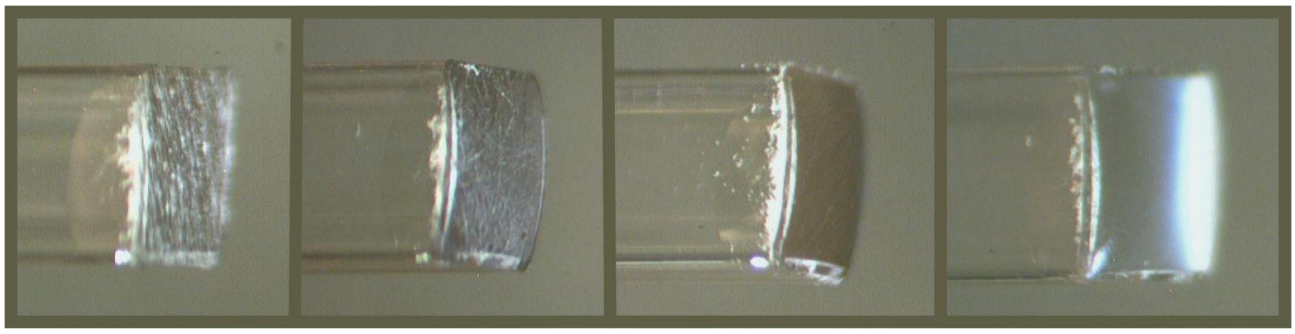

Figure 19: Example of how the instability of the polisher's hand affects surface contour.
Left to Right: Progression from End Mill surface finish to highly polished.

This was easily remedied by altering two of the procedures for cutting. First, as discussed earlier, the bundles were machined down to within a few thousandth of an inch of the metal support collar. This change ended up shortening the lever arm for the fibers and therefore in order to achieve the same deflection a much greater force must be applied. The second and more important change was made by having the cradle of the End-Mill move in such a direction as to have the cutting bit rotate into the bundle as it initially passes over the work. The trailing end of the bit turns in such a direction as to force the fibers away from the center of the bundle, but the amount of material that is removed by the trailing edge of the bit is miniscule and has been shown to produce virtually no damage to the cladding. Thoughts of increasing the size of the 5x5 bundles were partially countered by the fact that at present bundle size the bit of the End-Mill is only required to perform two passes in order to completely mill the surface of the bundle to a specific size. In other words the bit has a diameter of approximately 6 mm and for a larger bundle sizes more than two passes would be required to remove all bundle material to a lower height. The additional pass would inhibit the ability to always have the leading edge of the End-Mill bit turn into our work. At speeds of 1800 RPM a great deal of friction occurs which can produce substantial amounts of heat, especially at slow cradle speeds. The way any side effects due to the friction, i.e. fibers melting which can result in rough cleaving/cutting of material, is countered is by the use of a compressed air cooling system. The Air Chiller (see Figure 20) was designed and constructed in order to not only remove the heat generated in the bit and fibers, but also to assist in the removal of cut material to promote a cleaner cut. The Air Chiller is filled with an ice and water mixture which allows the air from the machine shops low pressure air system to be cooled via the submerged copper tubing and then directed through a nozzle at the material and bit.

Figure 20: Air Chiller.

The unit has been proven to provide sufficient cooling to mitigate melting and promote the brittleness of the material, thus leading to cleaner cleaving of the material. The trials, to date, have been so successful that no additional preparatory steps are required, once cut, if the waveguides and SciFis are being laser welded or spliced together. If optical glue is being used, then only about 5 minutes of polishing is required to get a bundle of fibers ready for gluing.

During the initial trials the focus was on the use of optical glue for attaching the SciFi to the waveguides, but recent developments have shown that the optical glue from Epoxies, Etc. may in fact be too brittle and might not provide sufficient strength to hold these components together reliably. The option of gluing the fibers together is still being researched, this time using BC-600 and other glues with the required optical properties. The problems that have lead to second thoughts about the use of optical glues have also directed the team to re-evaluate the procedures being used. The major hesitation for the use of optical glue came about when a

bundle of glued W/SciFis broke apart during an attempt to re-mill the end of the bundle. After a great deal of review it was determined that several procedural errors were at fault. Photos of the broken bundle (see Figure 21 & Figure 22) show a clean break on most of the glued surfaces.

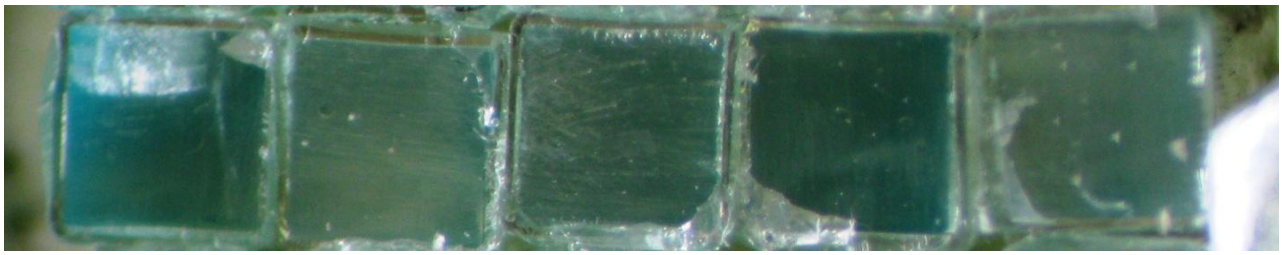

Figure 21: Shows the SciFi end of a broken glued bundle.
The clean breaks seen, indicate poor bonding of the glue to the fiber surfaces.

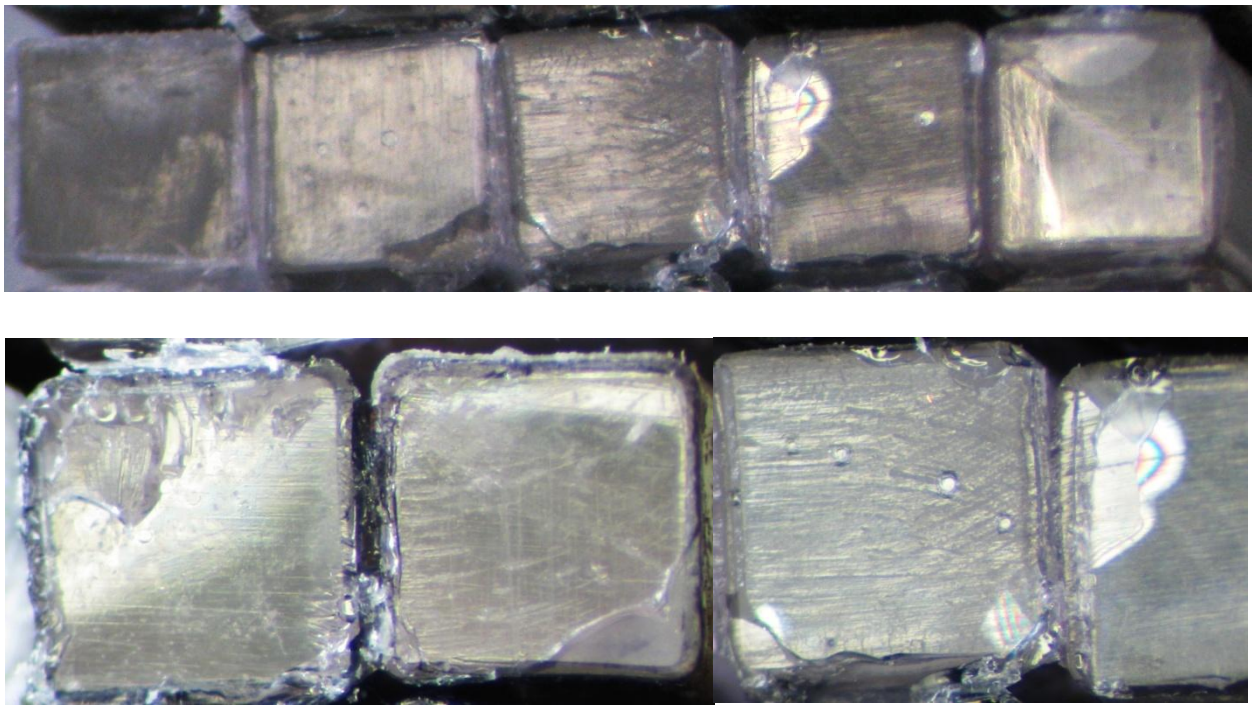

Figure 22: Shows the waveguide end of a glued bundle that was broken during an attempt to level the finished end of the SciFi with an End Mill.
The bottom right picture shows trapped air bubbles in the dried glue,
which were the result of the old gluing method.

The clean cleaving at the surface suggests inadequate bonding of the glue to the fiber's surface. The striations left on the glue support this idea since they are an impression of the surface of its counterpart fiber, which resulted from polishing the fibers prior to gluing. The failures of the optical glue resulted in a procedural overhaul and led to the discovery of flaws in the gluing procedure. As the photos in figure 21 and figure 22 show, the glue did not full bond with the mating surfaces of the fibers. A possible culprit is the procedure of highly polishing the fiber ends prior to gluing (see Figure 19). The polishing of the fibers to such a high degree was intended to provide maximum transmission across the interface once glued. Research led to the discovery that greater than 98% transmission across a 125 micron glue interface can be achieved for wavelengths above 400 nanometers (nm) if the fibers are lightly polished with No. 400 Silicon Carbide paper, cleaned with methanol, and dried prior to gluing. This degree of surface polishing is almost equivalent to the polish that is attained directly from the use of the End Mill. Further testing is required, but a coarser polish may lead to a better bonding between the optical glue and fiber surface. The other discovery of significance was that optical glue takes several days to obtain maximum strength. Initial testing on the fibers was typically performed between 4 to 24 hours after they were glued. These two procedural changes may lead to the revitalization of the use of optical glues.

As a result of the numerous gluing trials we have achieved an optimal procedure for gluing the fibers which has virtually eliminated almost all of the drawbacks to gluing. The three main problems that were encountered during the initial attempts to glue the SciFis and waveguides together were: excess glue seepage, fiber misalignment, and entrapped air bubbles in the glued fibers. Let us discuss the later problem first, entrapped air bubbles in the glued fibers. The most prevalent problem to this occurrence results from the degradation of the optical properties of the fiber core. As the light passes from the SciFi to the waveguide any change in the index of refraction of the material causes an increase in the probability of the light being deflected out of the core and never making it to its intended final end point, the SiPMs. The problem of air bubbles in the glue stemmed from two basic procedures which were part of the older gluing process. The first procedural process which augmented the introduction of air

bubbles into the system of gluing was the mixing of the glue itself. The optical glue which is used comes as a two part mixture, epoxy resin and hardener. These two components are measured out and mixed together just prior to application on the fibers. When mixed the glue has a viscosity of 800 centipoises (cps) at room temperature. The viscous nature of both the resin and hardener not only made it difficult to mix the two but also caused most of entrainment of air in the mixture during the blending process. Fortunately, the working time for this glue is sufficiently long enough to allow for attempts at reducing the entrained air to be made. Older procedures included the heating and popping of surface bubbles with the syringe used to apply the glue. Unfortunately, these attempts only helped in slightly reducing the presence of air bubbles. Therefore, a procedure was developed that not only eliminated all entrained air bubbles from the mixed glue but also increased the working time available by reducing the time required to remove entrained air. Upon completion of thoroughly mixing the two part glue, the container holding the glue is placed on a vacuum plate and a bell jar is placed over it (see Figure 23).

Figure 23: Vacuum chamber set-up.
The red cup contains a sample of mixed epoxy.

Immediately a vacuum pump is started and a vacuum begins to form inside the bell jar. At around 15 inches of mercury (Hg) vacuum the container of glue begins to bubble rapidly while it releases the air that is entrained within it. After a minute the release of air from the glue stops and the surface of the glue becomes littered with un-popped bubbles. Upon release of the vacuum within the bell jar, the surface bubbles pop and clear glue with no entrained air emerges. This procedure virtually removes the problem of air in the gluing process (see Figure 24).

Figure 24: Stages of removing entrained air from the glue.
Left to right: Air entrained glue, release of air bubbles under a vacuum, clear bubble-free glue.
The glue to the left has a dull yellow color to it with tiny black dots throughout, both of which are a result of the trapped air in the glue. The glue to the right has a very clear appearance to it similar to water since the entrained air has been removed from the glue.

Unfortunately the old procedure that was used for gluing reintroduced the air problem while applying the glue and also tempted the gluer into using too much glue. The old way of gluing had the fibers aligned with a small gap between the two and relied on capillary action to draw in the glue, which was applied via a syringe, to fill all voids (see Figures 25a & 25b). Unfortunately excess glue was required in order to completely fill this gap and the excess tended to wick down the length of the fibers and glue the fibers to the mounting block, which often ended in a glued assembly being broken during the removal process from the gluing station.

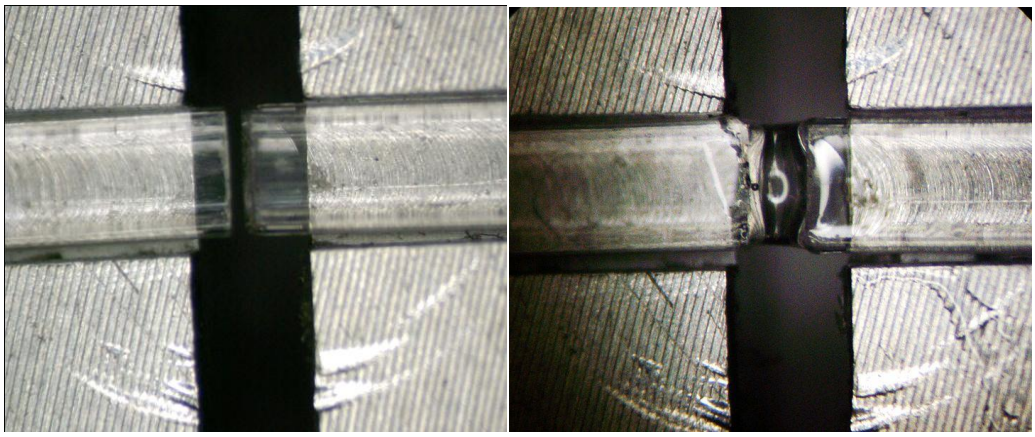

Figure 25a Figure 25b

Figures 25a & 25b: Older method of gluing.
Figure 9a: Alignment of unglued fibers.
Figure 9b: Result of gluing fibers using capillary action.

The latest procedure uses the equipment from previous trials but in a new way. The fibers are still mounted in the gluing station (see Figure 26) and aligned so that a uniform small gap is formed between the SciFis and waveguides when the two parts of the gluing station are pushed together. Then the two parts of the gluing station are separated and placed on their ends. One way to visualize this is to look at figure 26 and consider the bottom picture but with the two outer most components connected to the top of the inner components on their respective side. Then envision turning the right and left part of the gluing station clockwise and counter-clockwise, respectively. This allows for the mating ends of both the SciFis and Waveguides to be exposed and parallel to the ground.

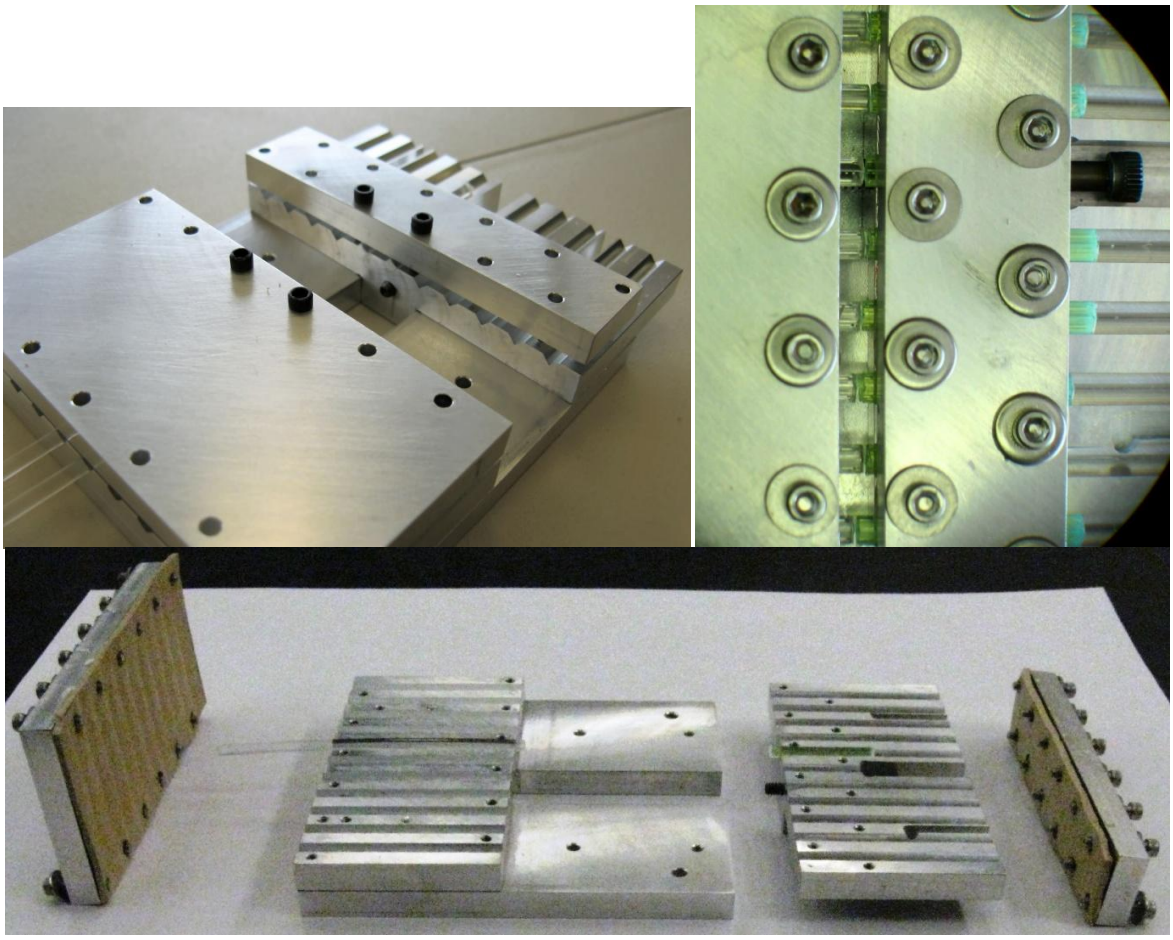

Figure 26: Gluing station.
Top left: Gluing station with fibers separated.
Top right: Close up with fibers pushed together.
Note: the black set-screw is used to fine tune fiber separation.
Bottom: Exploded view.

Next a syringe is filled with glue as before but this time the glue is carefully applied to the surface of each fiber. Special care is taken by using a magnifying glass to apply approximately one half to two thirds of a drop of glue to each fiber. The magnifying glass assists us in this process by helping to ensure that the complete surface of the fiber ends are coated with a thin layer of glue. Most applications of the glue end up spreading across the entire surface but occasionally the surface tension of the glue is too great and a mound of glue is formed in the center of the fiber. Fortunately this is easily remedied by using end of the needle of the syringe to gently drag the bubble across the surface of the fiber, thereby coating it completely. Once

both the SciFi and Waveguide ends have been completely coated with a thin film of glue, the half of the gluing station that contain the SciFis is placed back into position on the other half of the gluing station and these two sections are pushed together. The capillary action which occurs along with the fact that both surfaces have been completely coated helps to virtually prevent any entrapment of air bubbles in the glue. Additionally, the reduction of approximately 2 to 3 drops of glue from each fiber pair during the gluing process helps to reduce the flow of glue from the mating surfaces of the fibers and has increased the productivity as a result of reducing fiber loss during gluing.

An additional method of fusing the fibers using laser welding is also being considered. Research into laser welding the fibers has taken two paths: contract manufacturing and in-house welding. A number of companies that specialize in laser welding of plastics have been contacted and samples have been shipped for testing with some results still pending. The initial results show that most companies are ill-equipped to handle the size and type of fibers that GlueX is using. The samples that have been returned to UCONN after testing indicate that the Carbon Dioxide (CO_2) laser, which was used, applied too much energy to the system and caused the fibers to liquefy and not bond together. As for the in-house method of laser welding the fibers, an Excimer Laser (see Figure 27) has been procured and is currently being set up for testing.

Figure 27: Excimer laser.

Numerous calculations and simulations have been run to determine the best approach for the optics and power level to be used. Since this laser has been sitting idle in a lab since 1998, a fair amount of upkeep was required to make the laser ready to make first light. Numerous o-rings were replaced in order to pass vacuum seal tests and gas purging of the system with Argon was conducted. The refurbishment and set-up of the excimer laser has been conducted in the laboratory of Dr. Barrett Well's at the University of Connecticut. The transfer of the laser to a new laboratory required the installation of ventilation, power supply (3Φ, 208 Volts), supports for the mounting of the laser, and cooling water distribution and collection. The only hold up in running tests is the procurement of specialized gases (e.g. Argon with Helium and Fluorine gasses) for the laser, which are currently on order. Numerous man-hours are being spent on the refurbishment of this laser since it is intended to play a dual purpose in the GlueX project. The main propose for the Excimer laser is not the welding of fibers, but the thinning of diamond (diamond radiator), which is to be used to create a photon beam via bremsstrahlung, by laser ablation.

Development of the Tagger Microscope

(Prototype for the Gluonic Excitation Experiment)

Although no definitive studies have been conducted, it is estimated that 5 to 10 diamond radiators are required each year due to radiation damage. The standard techniques of mechanical abrasion, which is known to work, have limitations such as: poor surface finish, extensive sub-surface damage, low removal rates, and poor scalability in manufacturing. Due to these limitations three alternative ways to get the thin diamond wafer (20 microns) required for the diamond radiator are being explored. The three methods are: Laser ablation and reactive ion etching, ion implantation with chemical etching and lift-off, and chemically assisted mechanical polishing. Laser ablation consists of using a pulsed UV laser to ablate (vaporize) material from the surface of the diamond. Each laser pulse will create a pit in the surface of approximately 100 microns in diameter. Rastering the beam over the diamond creates a smooth surface with only sub-micron roughness. The residual amorphous carbon on the surface is removed by chemical reaction (e.g. ozone, Reactive-Ion-Etching (RIE) process). The ion implantation technique consists of setting ion beam energy for a specific penetration depth and sweeping over an area of the crystal. The crystal is then heated which anneals the crystal and converts the thin deposition layer to graphite. A laser drill then trenches around the edges and a solution is injected to etch the graphite but not the diamond. The final step of removing the crystal is performed by brazing a thin wire to the substrate and lifting it off. Extremely thin crystals of 400 nm have been made using this method, but thicknesses on the order of 20 microns have never been considered. Dr. Richard Jones of the University of Connecticut has been in contact with personnel who currently use this technique in order to ascertain its possible feasibility to the GlueX project. The third method of chemical polishing is being sought through collaboration with Sinmat Inc., Gainesville, Florida. Sinmat has developed a technique that utilizes a chemical assisted polishing method in which initial trails have shown to drastically reduce the damage to the diamond surface and decreases the time needed to process the material, in relation to traditional mechanical polishing. A chemical coating (Ceria) is used to coat slurry particles made of Aluminum, Silicon Carbide, and diamond. The chemicals coating the slurry particles undergo pressure-catalyzed reaction with the diamond surface and mechanical abrasion is used to remove the softened surface material. Sinmat has submitted a

proposal for a Small Business Innovation Research (SBIR) grant and is awaiting approval for phase I, a one year feasibility study.

The approaches of other experiments to the problem of fusing fibers have been researched and contacts with these labs have been made. In particular, ties between personnel at Michigan State University (MSU) have been formed and the splicing unit (see Figure 28), which they developed, has been shipped to the University of Connecticut courtesy of Ron Richards and is currently being setup for testing.

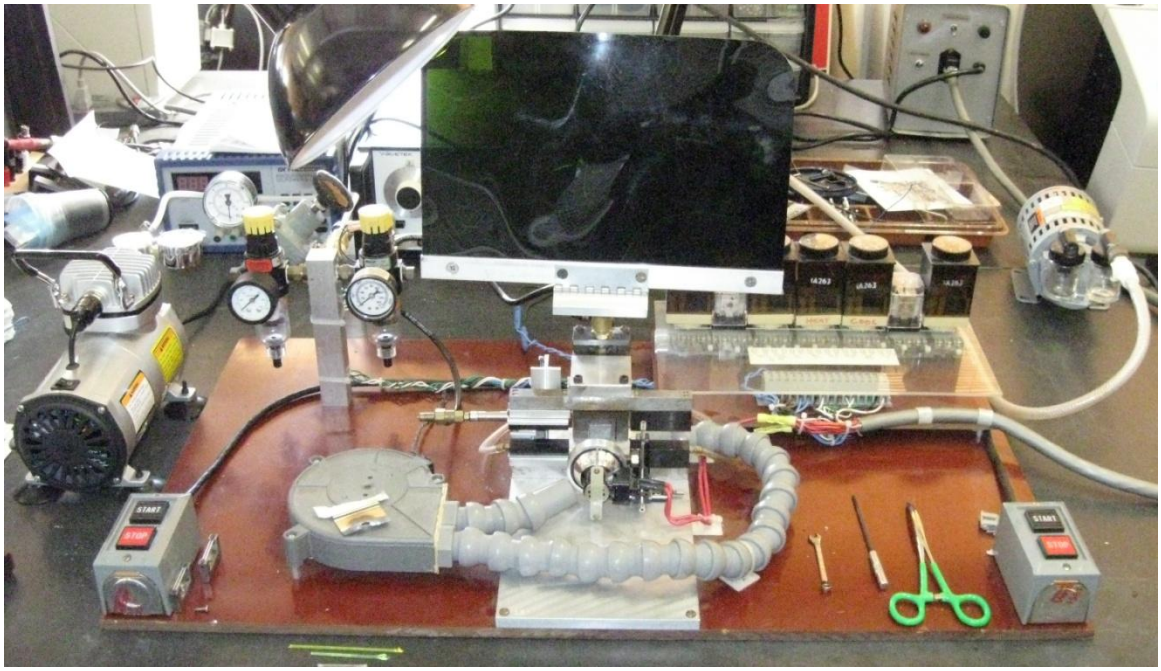

Figure 28: MSU Splicing Unit.

This unit uses a high intensity lamp directed at the fibers through a small hole in a metal plate, which acts as a collimator, thereby allowing heat to be directed only at the splicing area of the fibers. Additionally, a forced air cooling system is directed at both the fibers and heat lamp. At each end of the unit there is a set of blocks which come into physical contact with the fibers. These blocks serve to hold the fibers in place and also provide a force to push the fibers together during the splicing process. A set of small holes have been drilled into a groove on each lower block and fittings are attach to the blocks which connect to a vacuum pump. A

small glass tube is used to encapsulate a section of the fibers, between the blocks, which are being fused. This specially made glass tube serves several purposes. First it provides perfect alignment of the SciFi and Waveguide throughout the fusing process. Secondly the clear glass tube helps to maintain the shape of the fibers during fusing. In order to fuse the fibers we must attain a temperature close to the melting point of the material. Since the cladding has a lower melting point than the core, which must be completely fused in order to obtain the maximum optical properties that are required, we can conclude that there is a high probability of melting off the cladding prior to completely fusing the core. By having the glass tube we provide a way to contain the melting cladding, maintain alignment, and preserve the precise square shape of the fibers, all of which are require to provide a viable fused fiber. Third the glass tube helps provide a way to draw heat from the fibers during the cooling process. The forced cold air system provides forced convection to cool the glass, therefore a large temperature gradient between the glass and fiber maximizes cooling of the fused fiber.

The major difference that was discovered about the fibers used at other laboratories and the fibers which are being utilized for the GlueX project, other than the fact that most other laboratories have used round versus square fibers, is the materials used for the core and cladding. The fibers used for GlueX are a multi-clad fiber with both Acrylic and Fluor-acrylic used in the cladding and Polystyrene used for the core, while most other laboratories have chosen fibers that use the same material for both the core and cladding which is equivalent to the materials the GlueX project cladding is made of. This difference becomes an issue due to the drastic variation between the melting points of the material in the core versus the cladding. When the core and cladding materials have the same or even similar properties, i.e. melting point and boiling point, the temperature distribution across the fiber as they are laser welded is not as much of a concern. In the GlueX project's case, the boiling point of the cladding material is only 40 ^{o}F above the melting point of the core material, therefore a great deal of consideration must be given to focus the laser and provide a pulsed beam so as to heat to core enough to allow complete fusing of the core but at the same time prevent heating the cladding to the point of boiling away. Simulations have shown that a majority of the heat is drawn away

via forced convection instead of conduction through the length of the fiber. With this knowledge the intention is to use a focused pulsed laser, which provides sufficient attenuation in the material, while simultaneously cooling the cladding by using a forced cold air system.

The next to last step of W/SciFi length preparation prior to installation into the tagger microscope will include annealing of the fibers to a predetermined shape. Essentially the fibers are heat treated and then cooled all while under stress, e.g. bent to a particular shape, in order to give the material a contour similar to the shape that it is required to take while mounted inside the tagger microscope. This reshaping serves several purposes including the reduction of stresses on the fibers once mounted and the facilitation of mounting the fibers in the confined space of the tagger microscope. The shaping, heating, and cooling of the fibers bundles is achieved through the use of a preformed Polyvinyl Chloride (PVC) pipe (see Figure 29) in which the bundles will be mounted.

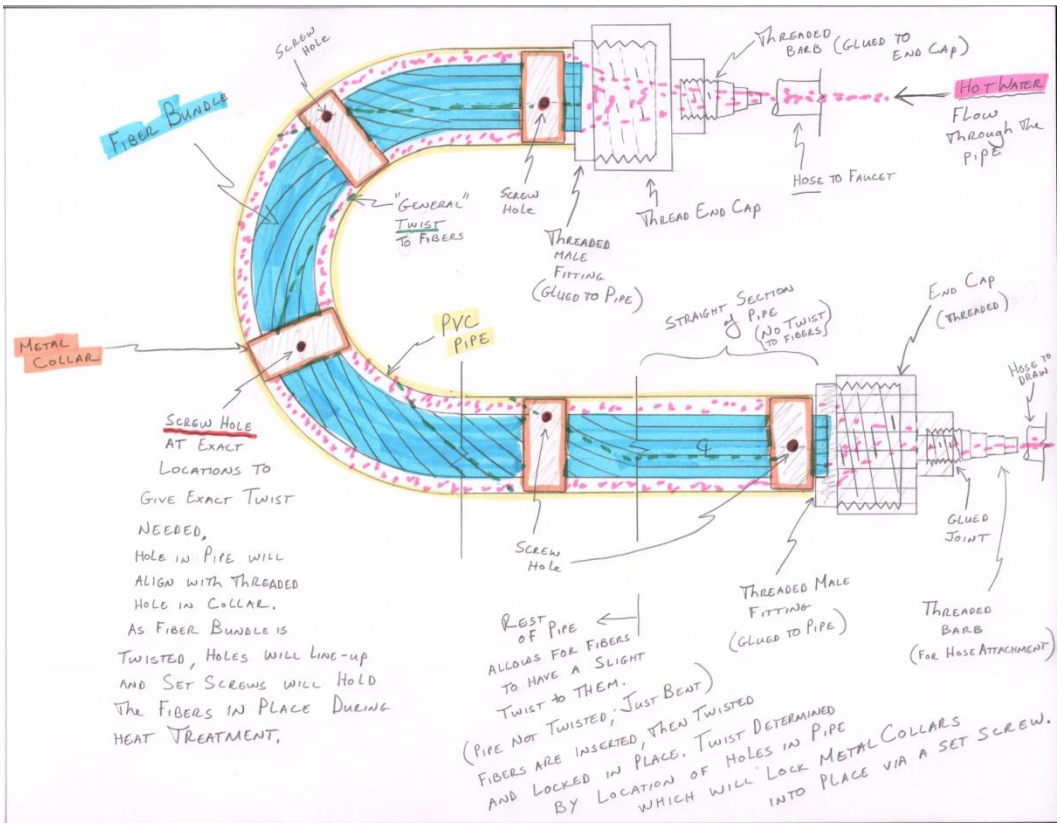

Figure 29: Design concept for the PVC pipe used to heat treat fiber bundles.

The mounting of the bundle in the pipe is accomplished by having screws placed through the pipe and into the metal support collars around the bundles. By having proper spacing of the support collars, e.g. in the length direction, and specific location of holes drilled into the PVC pipe we are able to give not only a bend to the bundle but also a twist to it along the length direction. Since a schedule 40 PVC pipe is being used, the pipe wall thickness is enough to support the stresses that occur from the bending and twisting of a fiber bundle. Once the fiber bundles are secured in place then end-caps are screwed onto both ends of the PVC pipe. These end-caps will have fittings, e.g. barb fittings, on them to allow for connection of rubber tubing. One of the rubber tubes is connected to the laboratory faucet while the other rubber tube is placed into the drain. Once the pipe is filled with hot water and any trapped air is removed, the flow is reduced to a minimum which allows for a constant temperature of water to be maintained. The hot water flows through the pipe for several minutes during which time the fiber bundles reach and maintain an equilibrium temperature. Soon after the fibers are heated to equilibrium the water can be secured. The rubber hoses should be clamped and the end-caps should be left on to allow the fibers to cool more slowly. After the pipe and components reach ambient temperature the individual fibers are removed and ready for painting once dry.

Upon completion of fiber cutting, polishing, gluing, and heat treating the fibers are ready for the final two preparatory steps before mounting. The next step after heat treatment is to paint the outer cladding of the fibers. The painting of the cladding of the fibers with black paint is performed to prevent/reduce the transmission of a signal from one waveguide to another. This is an issue since the fibers are being packed together in tight 5x5 bundles that are mounted side-by-side horizontally. As the fibers separate from the bundle to connect to the chimney and electronics, the problem of signal transmission from one fiber to another becomes a non-issue since as the air gap increases the probability of transmission is drastically reduced. Initial painting trials were performed by simply using a can of black spray paint held at a considerable distance from the fiber. The initial trials should that this method was not a viable way of painting fibers since the paint was applied too thick and tended to leave areas uncovered (see Figure 30).

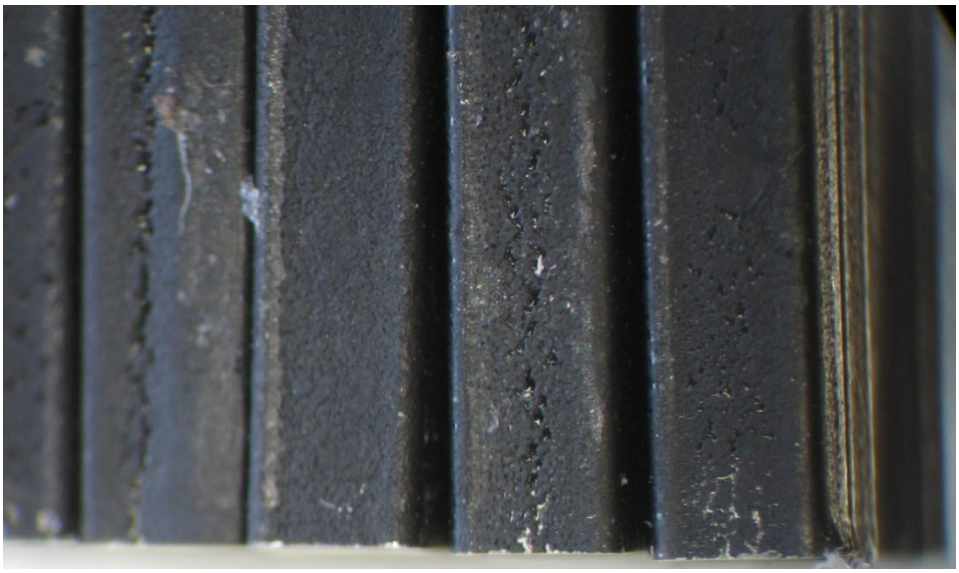

Figure 30: Painted fibers using a can of spray paint.
The darker areas down the center of the fibers show areas that were not covered by the paint.

A mini oil-less compressor and air brush system (see Figure 31) with a 1/5 horsepower motor was procured and tested. It was shown that by lightly thinning the paint, a thin coating could be applied to the fibers with no apparent spots of non-coverage.

Figure 31: Air brush and compressor.

Additional procedures were tested for polishing of the fibers and should be noted even though they were deemed either unviable or unnecessary. An attempt was made at using a chemical to expedite the polishing of fibers. It was found that this chemical provided no significant benefits to the polishing procedure, but did in fact have a negative effect on the cladding material. The polishing chemical seemed to make the cladding material softer and more prone to flaking away from the core. In addition the chemical paste was inclined to being forced up into the spacing between the bundled fibers and creates additional problems. Another attempt was made to speed up the polishing process by using liquid nitrogen to cool the fiber bundle prior to polishing it on copier paper, which was the preferred grit media for polishing. The colder temperatures appeared to lower the required time needed for polishing, but caused problems once condensation formed and caused our grit media, copier paper, to change properties and become unusable. The idea of using liquid nitrogen for cooling the fiber bundles prior to and during cutting was considered but was rejected for numerous reasons and instead the air chiller system, that was previously mentioned, was used in its place.

Electronics

The objective of the tagger microscope is to measure the location of an electron which caused the production of a photon that interacted with the target, a helium nucleus, causing an excited meson. By measuring the electron's location using the SciFi bundles of the tagger microscope one can determine its energy and thereby calculate the energy of its counterpart photon which was a product of bremsstrahlung resulting from the influx of electrons through a thin diamond crystal. Many of the components needed throughout this process have previously been mentioned, but in order to transfer the data stream from the SciFis numerous electronic elements are required. The light signal produced within the SciFi by its interaction with a charged particle, e.g. an electron, is transmitted through the waveguide by way of electromagnetic waves. This electromagnetic signal must be converted to an electronic signal

so that the data may be interpreted and put to use. In order to convert this data stream to a useful format, the GlueX project uses three basic electronic boards: Amplifier Board, Backplane, and Digital Control Board (see Figure 32). Each board plays a crucial part in the transfer of a light signal to a digital signal.

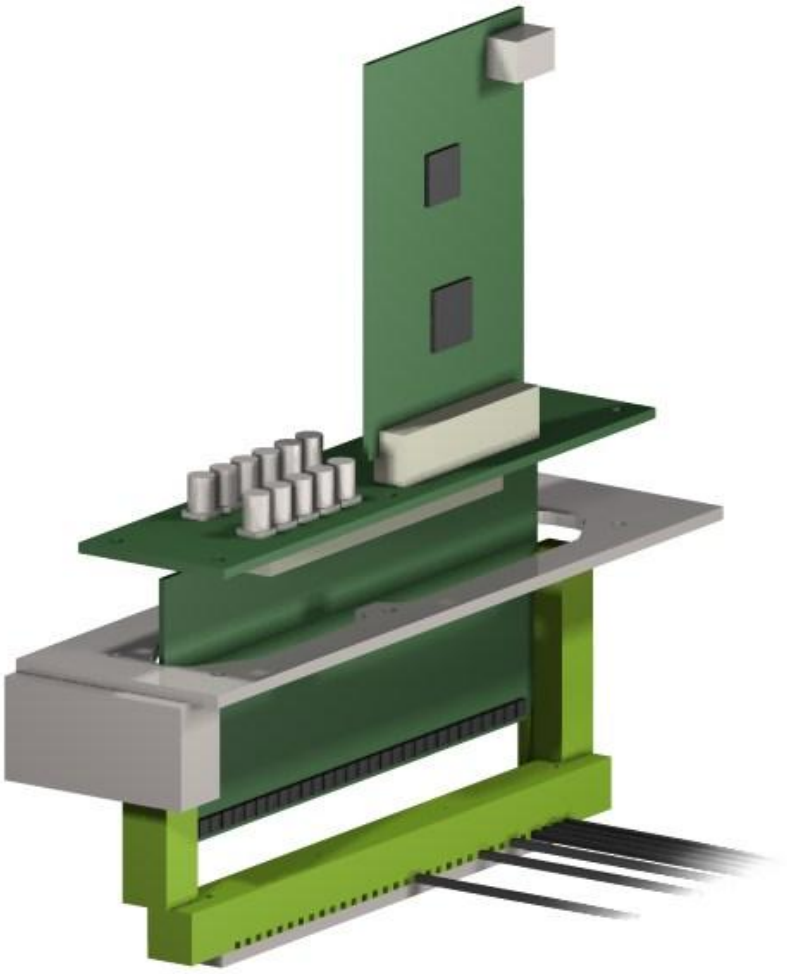

Figure 32: Rendering of the configuration of the electronic assembly.

There will be one Amplifier Board (see Figure 33) per bundle of 25 W/SciFi containing 25 Silicon Photo Multipliers (SiPM), one for each W/SciFi. Each Amplifier Board provides space for mounting the SiPMs (see Figure 34), initial signal amplification, and summation circuitry.

Development of the Tagger Microscope

(Prototype for the Gluonic Excitation Experiment)

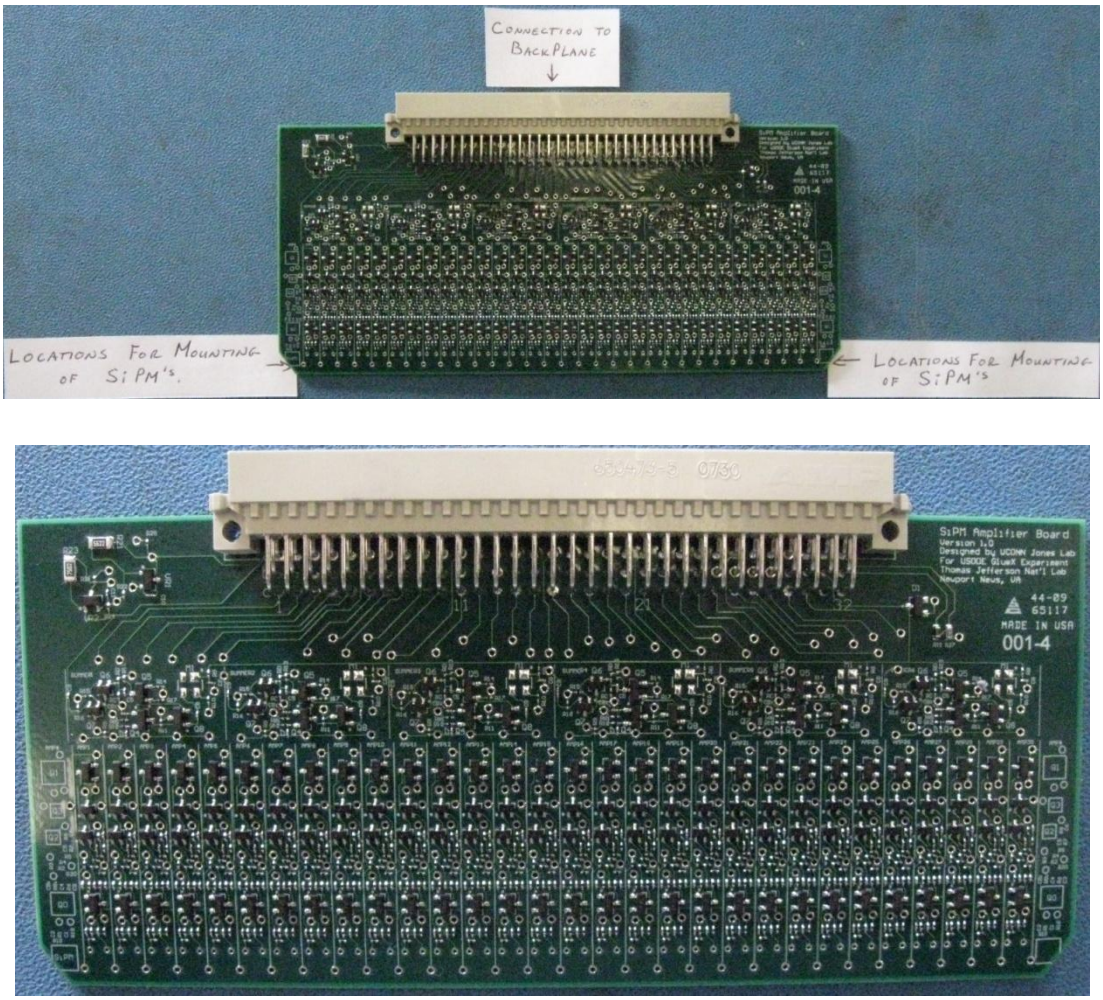

Figure 33: Amplifier Board.

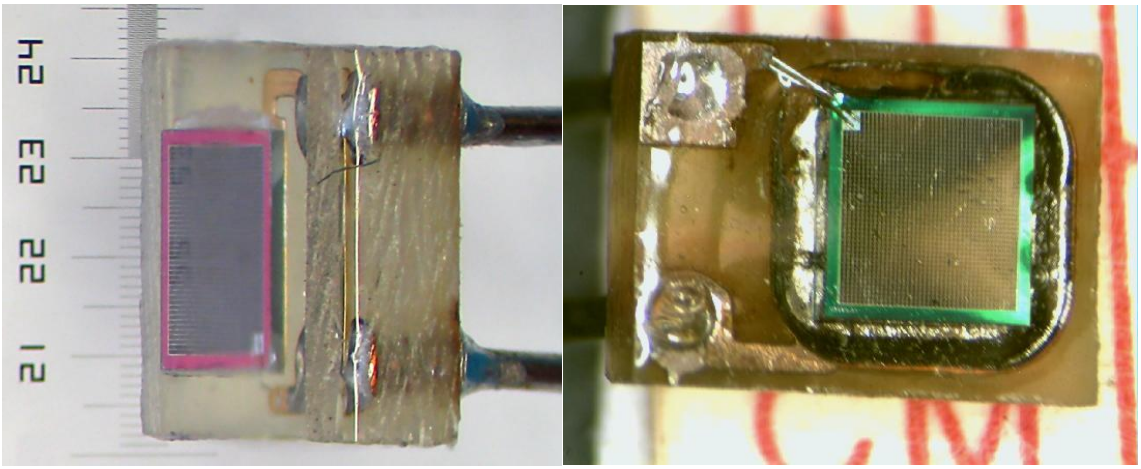

Figure 34: Silicon Photo Multiplier (millimeter scale).

The SiPMs are the direct link between the light signal and electronics. They can provide for a conversion of a single photon via an avalanche photodiode array. The SiPM produces a small current pulse which has to be converted to a large pulse of voltage. The Transimpedance Amplifier Circuitry is used for this conversion from a small current pulse to a large voltage pulse. The amplifiers are equipped with online selectable gain control and online controllable bias voltages. Therefore, a uniform quality of readout of all the optical channels can be maintained during runtime. The signals from all five SciFis in a column are combined via the Summing Circuitry, since the energy in any of the SciFi's of a column have the same energy. One of the most important considerations in the Amplifier Board design was the target acquisition system. The tagger microscope is to be readout with a 12-bit flash Analog Digital Converter (ADC) with a sampling rate of 250 MHz. The dead time of a channel, which can be considered the duration of the amplified signal, has a lower bound set by the decay time of the SciFi that was selected and an upper bound set by the sampling rate, 2.7 ns and 250 MHz respectively. All told there will be approximately 500 amplifiers in the full scale tagger microscope and this can pose a risk to other components within the housing structure that are more sensitive to higher temperature ranges, e.g. SiPMs, if power consumption for the amplifiers is set too high. The power consumption per amplifier has been set to 30 milliwatts (mW), based on the confined space in the housing structure and the large number of amplifiers required, since each board will contain spares. The SiPM Digital Control Board (see Figure 35) is used for communicating with a computer via an Ethernet interface.

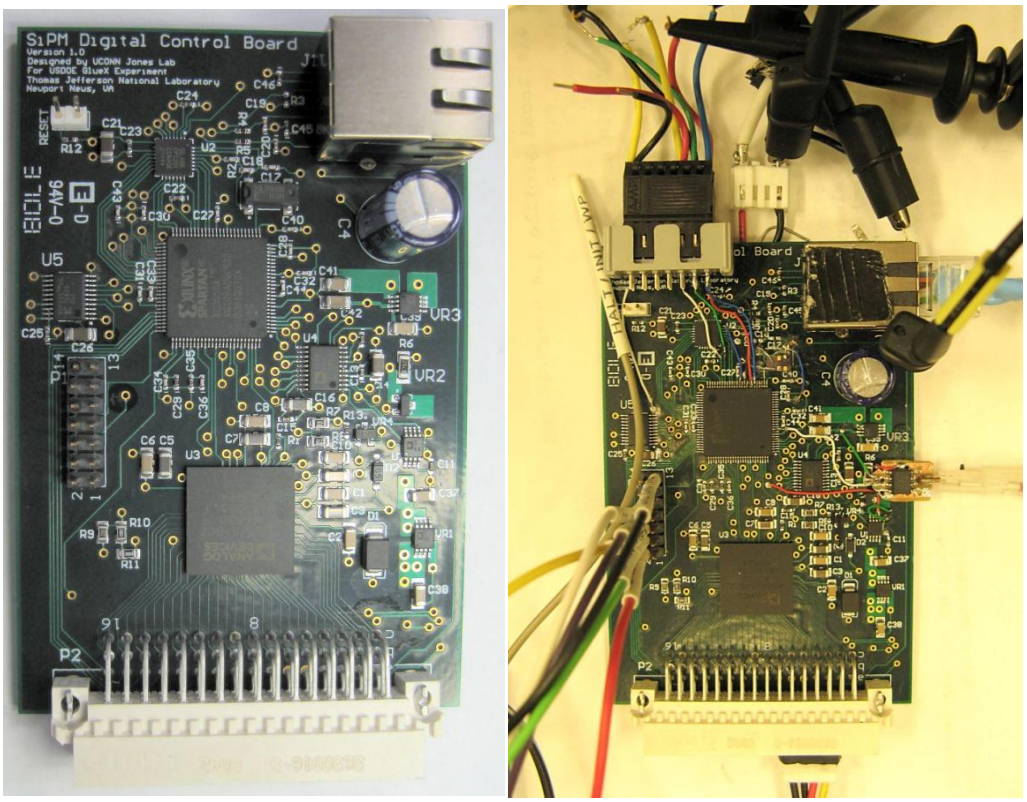

Figure 35: SiPM Digital Control Board.
Left: Populated Board.
Right: Taken during de-bugging.

This interface can be used to set the bias voltages and also send queries about voltages and temperatures at different points within the electronics. The Digital Control Board contains four main components: Field Programmable Gate Array (FPGA), Digital to Analog Converter (DAC), Analog to Digital Converter (ADC), and Ethernet Controller. The FPGA controls and monitors all other components on the board, while also accepting commands from the Master Computer. The DAC takes commands from the FPGA and outputs bias voltages to the SiPMs on the Amplifier Board. While the ADC measures critical voltage levels in the Tagger circuitry and reports these back to the FPGA. The Ethernet Controller is used to convert signals from the FPGA into standard computer networking signals, which allows for simple connection to the Master Computer. The Backplane is the interface between the SiPM Digital Control Board and the Amplifier board. It not only provides for the interface between the two other electronic boards through Eurocard connectors but also provides a light seal for the penetrations in the

housing structure which is required to access the Amplifier Board. During the design of the Backplane an extra layer of pure black FR-4 was added to the board in order to obtain the required opaqueness which would provide the light sealing qualities needed. A relatively thick layer of rubber gasket (1.3 mm) will be used between the board and the housing of the tagger microscope to provide completeness in the light sealing. Due to the thickness of the gasket material a concern was raised about possible bowing of the Backplane since the securing screws are on the four corners of the board. This concern and an apprehension about misalignment of the SiPMs with the waveguides in the chimney were both alleviated by a new design change. In the past the idea was to have the Amplifier Board suspended in place by its Eurocard connector connection to the Backplane with only two piece of plastic, inside the housing, acting as runners on each side. This design elicited concerns with regards to alignment and reliability. It was thought that human error could cause the connector to not be fully inserted therefore misaligning the SiPMs and waveguide chimney. In the new design the Amplifier Board would no longer just be guided into position by plastic runners but instead have a bottom support at the end of these runners which provided a hard stop for the card. Calculations have shown that if the gasket material is removed from directly under the support screw holes and a small metal washer is inserted in place of the gasket material, then the Backplane can be securely tightened down without any worry of bowing the board and possibly allowing light in. Since the gasket material is slightly thicker than the metal washer, the Backplane can be secured down fully, providing a secure light seal and having the bottom of the Amplifier Board come to rest on the hard stop. This provides perfect alignment of the SiPMs and waveguides without any unnecessary stresses. As stated throughout this paper, the GlueX experiment uses several different methods to fine tune the data stream collected and statistically process the data so that accidental tags and noise can be eliminated. The electronics play a crucial role in this data filtering, such as allowing the ability to adjust the gain or bias voltage and interface with components directly.

Housing Structure

The housing structure will be centered at the cross-section of the vertical focal plane and the parallel-to-point focal plane created by the quadrupole magnet and dipole magnet (respectively). The housing structure is mainly composed of aluminum, with the exception of the guides (runners) for the Amplifier Board. The main housing frame consists of 3 inch L-shaped angled aluminum (ASTM B308). This framing is larger than what is structurally needed but is helpful when constructing components and with the stability of the unit. Aluminum was chosen as the main construction material based on its relatively low density and sufficient structural strength. The housing height and width are primarily based on the requirements of the W/SciFi's. In order to conserve space but yet provide accessibility for assembly and repair, it was chosen to have the fibers curve back over themselves when going from the bundle to the waveguide chimney. The height of the light sealed compartment was selected based on a reasonable radius of curvature that the fibers could obtain without damage or excessive stress. The housing width was calculated based in part on the SiPM Digital Control Board width and the size of the parallel railing system. Since the fibers are to be offset by only 7 to 10 degrees off the z-axis of the housing structure, the fibers end up curling back over themselves to connect to the waveguide chimney. The waveguide chimney (see Figure 36) is used to secure the end of the waveguides so that they align precisely with the SiPMs on the Amplifier Board.

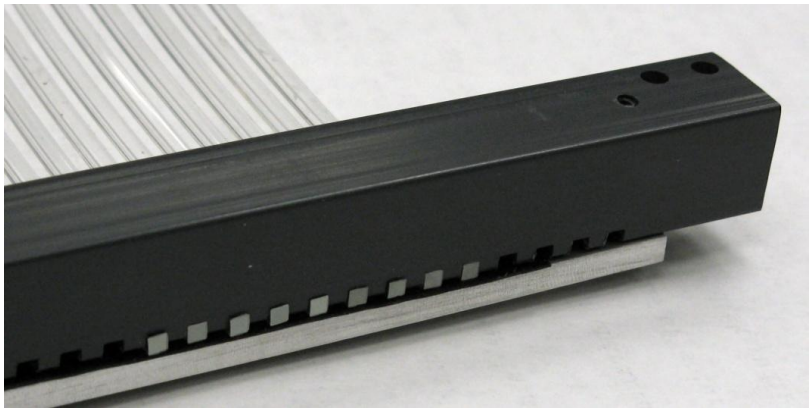

Figure 36: Waveguide Chimney
(Does not show entire chimney)

Since this alignment is so essential to the transfer of the light signal to a digital signal, a special guide and stop was designed for use with each Amplifier Board. The two guides (runners) that make up part of one assembly are suspended from the top plate of the housing and have a bottom hard stop connected. The guides are made of plastic stock with a slot milled into the side to allow for the Amplifier Board to travel freely, yet securely, down it. The bottom hard stop is also made of the same plastic stock but is simply secured firmly to the two guides. The bottom hard stop has no need for grooves since the guide slots run the full length and it has been determined that the forces on the Amplifier Board does not cause it to bow or deflect away from the waveguide chimney. The parallel railing system is mounted to the base plate of the housing structure, which is made from an Aluminum plate (see Figure 37).

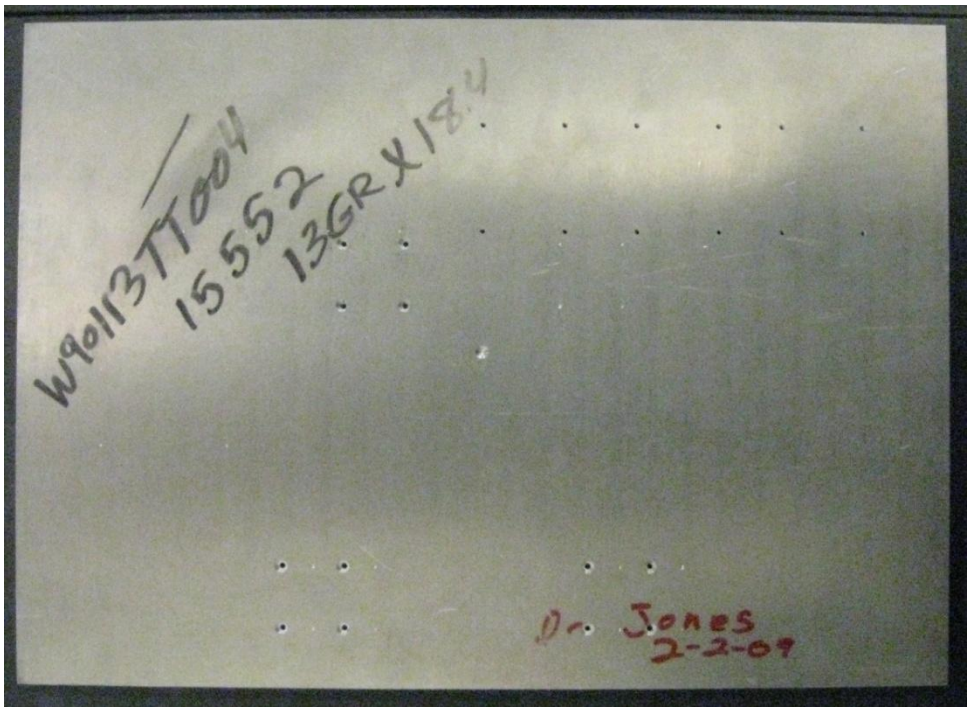

Figure 37: Base plate used for the prototype.
Note: The picture shows the base plate mid-way through the fabrication process.

Predrilled holes allow for perfect alignment of the parallel railing system, step motors, and power supplies. The base plate/housing structure is suspended off the surface of the laboratory floor by a mounting bracket that supports the housing structure and allows it to

rotate around the z-axis (parallel to the length of the railings in the parallel railing system). The mounting bracket consists of an aluminum plate similar to the base plate but slightly larger in size and two brackets one on each end of the mounting bracket plate. The mounting bracket plate sits flush to the laboratory floor with the two brackets, supported to the plate by bolts, extending upward from the floor. The brackets have a hole near the top with a specially fabricated rod through it. The rod is fabricated from a two and a half inch stock of cylindrical metal, with each end having approximately an inch of thread cut into it. The half inch of cylindrical stock that is left between the threaded ends acts as a frictional stop, with the aid of lock washers, when the housing structure is angled and the nuts are tightened to secure the structure in place. This design helps with the alignment of the microscope during prototype testing, since this testing is conducted using an electron beam which is coming from the ceiling of the laboratory. The suspension of the base plate also allows for the mounting the step motors on the underside, along with their controls and power supply.

The two side plates and top plate used for the light sealed chamber are securely fastened to the frame using self tapping screws. In addition, the mating surfaces of the frame and these plates are covered with light sealing black caulk prior to installation. The back plate is installed using wing nuts and rubber gasket. The reason for this is that continual access to the light sealed chamber is required, especially during the initial testing phase. Testing includes the use of cameras inside the chamber to ensure that there is a proper light seal. The rectangular shape of the housing structure is slightly interrupted by the design of the section facing the influx of electrons (front section). This interruption comes in the form a slight inset of the frame from halfway down the height of the structure to the bottom. This offset has been introduced to minimize the possibility of scattering from an electron incident upon the structural frame. The minor offset and the location of the parallel railing system is intended to minimize the introduction of accidental tags into the data stream. The top half of the front section will be covered with a solid aluminum plate in the same manner as the side and top panels. The lower half will be covered with a thin opaque Mylar film to allow for the transition of electrons but

not light. The only special precaution that we need to abide by is the fact that the edges and corners of the supporting frame must be rounded in order to prevent tearing of the Mylar film.

Conclusion

With the use of components such as the three step motors and parallel railings, in our parallel railing system, not to mention the mounting bracket for the housing structure, we have afforded ourselves with the ability to manually and automatically control different aspects of our design. This flexibility in design allows for both the expected and unexpected occurrences which occur during testing. In addition, the ability to adjust different parameters, which have been incorporated into the design, permits things such as the alignment of the axes of the SciFis parallel to the incoming electron beam; therefore, permitting the opportunity of maximizing the light yield inside the SciFi due to an incoming electron. This increases the potential that a strong signal is registered for the event by the electronics. Improving signal strength gives a larger pulse height and therefore helps with the analysis of the data by allowing noise to be filtered out more easily and the larger time walk for the leading edge discriminator, which is being used for data processing, to be dealt with. Past consensus among physicists has been to limit the subtraction of signals to less than 10%, fortunately the use of statistical analysis allows for gathering of larger quantities of data and the subtraction of greater than 10% to achieve superior accuracy and virtually eliminate any time walk based on noise and shifting the level of the base line. Other components considerations have be invested into the design in the GlueX experiment to increase both tagger and counter efficiencies. In doing so we have been able to theoretically reach the intended goal of 95% counter efficiency. The design of the tagger microscope prototype permits the testing of these concepts and the designs that is to be used in the full scale model.

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