CONSTRUCTION PLAN FOR THE TAGGER MICROSCOPE & ACTIVE COLLIMATOR

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Over the past several years, the University of Connecticut (UConn) has developed prototypes and various drawings for GlueX's Tagger Microscope (TM) and Active Collimator (AC). These engineering drawings, along with the experience gained during prototype construction and testing have led to the procedures detailed below for the construction of the full-scale microscope and complete active collimator.

I. TAGGER MICROSCOPE

1. Fiber Rough Cut

1.1 Overview

The optical fibers from Saint Gobain Crystals were shipped to UConn on several ~26 inch diameter cardboard spools. Due concerns over UV light exposure, a single spool of BCF-20 (scintillating fiber) and BCF-98 (light guide) are stored on the end of the fiber cutting table in a light tight enclosure for construction use. The remaining inventories of fibers have been set aside in the manufacturer's shipping box for future use.

The fiber cutting table was designed as a dual purpose workstation. The following steps explain how this workstation is used to provide a way of cutting the fibers from their spools (a.k.a. rough cut). Later sections of this paper detail the use of parts of this workstation as an alignment tool for the long light guides during fiber splicing.

1.2 Procedures

- Don safety equipment: eye-protection & hearing protection.
- Ensure: sleeves are rolled up, hair is tied back, and jewelry is secured.
- Locate logbook used for data recording.
- Make sure the Dremel cutting tool is unplugged then visually inspect:
    - Ensure cutting wheel is secure and not cracked.
    - Verify electrical cord is in good working order.
    - Make sure the power switch is in the off position.
- Set cutting speed to 7.
- Plug in the Dremel tool.
- Check that the vacuum hose is secure and start the shop vacuum.
- Remove the tape holding down the end of protective cover over the spool storage box and flip the cover open to expose the two slots with the protruding optical fibers.
- Select a fiber spool to cut from and remove the rubber band holding the corresponding fiber in place.
    - Ensure the fiber is held securely prior to release of the rubber band.

    - If the fiber falls into the storage box:
        - Remove the side panel on the spool storage box using a razor knife to cut the tape.
        - Once the panel is removed, fish the fiber back through the slot at the top of the storage box and secure it in place.
        - Prior to closing the storage box, visually inspect the spools to make certain that the fibers are not fouled and the spools can rotate properly.
        - After inspection, position the side panel in place and secure with black duct tape.
        - Make sure that all exposed joints are covered.
- Place the fiber in the appropriately marked slot.
    - Start placing a wedge under the corner of all the spring loaded holder for the chosen slot.
    - Carefully feed the fiber under each holder.
    - Placing the end of the fiber against the nail that provides the fiber stop.
    - Next slowly place the fiber in the slot and remove the wedges from the holders to hold the fiber in place as you go along.
    - Work your way to the end with the notch.
- Hold the spool end of the fiber in place with your left hand.
- Cut the fiber along the notch with the Dremel.
- Turn off the Dremel and set it aside.
- Ensure that the spring loaded holder has the fiber firmly secured in place before letting go of the fiber.
    - If needed place the weight, which is affixed to the table with a cord, upon it.
    - Ensure that the end covered in sponge gasket is placed against the fiber, so as not to damage the fiber cladding.
- Carefully remove the cut fiber from the slot and wipe down with a lint free cloth.
    - To prevent flaring of the fiber cladding, start by wiping from the center of the fiber and continue the cleaning stroke until you are well past the end of the fiber. This will help to prevent any snagging and tearing back of the cladding from its core.
    - If debris remains on the ends of the fiber the vacuum hose can be used. Simply grip the fiber securely between the middle of your index finger and the pad of your thumb about one half of one inch from the end of the fiber. With the fiber parallel to the vacuum hose guide the end of the fiber close to the hose remembering to keep the end of the fiber centered in the middle of the hose end to prevent accidental contact and possible damage.

- Record the cross-sectional dimensions of the fiber in the logbook.
    - For SciFi: only one measurement at the center of the 3 cm fiber is required.
    - For light guide: align the fiber to the marks indicated on the wood guide and take the required measurements at the points designated by the markings.
- Visually inspect the fiber for damage paying particular attention to possible:
    - Cracks
    - Cladding flare
- If the fiber passes the dimensional limits stated in the specifications document and the visual inspection, place it in the storage box. All fibers that do not pass visual or dimensional inspection are to be discarded and recorded as non-compliant.

2. Fiber Straightening

2.1 Overview

The optical fibers received from Saint Gobain Crystals are shipped via large diameter cardboard spools. As a result, the optical fibers, when unspooled, tend to have an intrinsic curvature to them. It is very difficult to manipulate 30, 5+ foot curved fibers during bundle construction. For this reason the fibers are first straightened using a heat treating process. This process not only makes these fibers easier to handle during the construction process, but also helps to alleviate stresses within the fibers due to the manufacturing process. By minimizing the internal stresses of the fibers we can reduce the risk of crazing or fracture that otherwise might occur during the bundle manufacturing process.

2.2 Procedures

- Note: The fiber straightening procedure will require 2 technicians.
- Clean the bundling station table.
- Set out:
    - 5 light guide collars.
    - SciFi cutting collar.
    - Straightening plate.
- Don a clean pair of powder-free gloves.
- Move 36 rough cut SciFi and 36 rough cut light guides from the intermediate storage box to the bundling table.
- Bundle the SciFi's into their cutting collar.
    - Placing the large SciFi cutting collar flat on the table with the opening facing up.
    - Make sure the end screws of the collar are sufficiently loosened to allow all 36 SciFi to fit inside the collar.

    - Grab a handful of SciFi's and place them in the collar. Ensure they do not fall into the gaps between the cutting collar halves.
    - Continue to add the SciFi one-by-one until all 36 are inside the collar.
    - Check to make sure that the fibers sides are parallel to one another, and then slowly tighten the screws on the collar.
        - The screws must be tightened evenly, so work your way from side to side slowly tightening the screws.
    - Once the collar has just enough force to hold the fibers in place turn the collar upside down on top of the spacing plates. One plate fits under the top half of the collar while the other is under the bottom half.
        - These spacers are specifically designed so that an equal amount of fiber sticks out each side.
    - The fibers should slide easily up as a small amount of pressure is applied to mate the collar with the two plates.
        - If the fibers do not move with light pressure then simply loosen the screws until the fibers fall into place.
        - Due to the rough cutting process, some fibers might stick up a little higher than others. This is acceptable provided that the other side of the fiber makes contact with the table.
    - Torque the collar screws to 10 foot-pounds and test to ensure no slippage of the center fibers.
        - If slippage of fibers occurs, realign the fibers and torque the collars again.
        - In the event that fibers still slip then the collars may be torque to a maximum of 15 foot-pounds.
- Place the SciFi cutting collar into the intermediate storage box for later use.
- Separate the two halves of 3 of the 5 light guide collars.
- Loosen the screws on the remaining 2 collars.
- Attach the collars to the straightening plate.
    - Note: the collars are to be mounted so that the vertical portions of the bottom halves are as close to the back of the straightening plate as possible. Placing the collars the other way will prevent access to tighten the lower mating screws due to the straightening plate.
    - Start by screwing the two collars that have both halves still attached into positions 1 and 5 on the straightening plate.
    - Next screw the bottom halves of the remaining three collars into positions 2 – 4 on the straightening plate.
        - The bottom half of a collar is the ones with male threads, not through holes at the mating surface of the two halves.
- Bundle the light guides into their cutting collars.
    - Carefully feed the light guides one-by-one through the two end collars

allowing the center section of fiber to lie on the three bottom collar halves.

- This may take a little time. It helps if the fibers are all orientated with their curvature in the same direction. Having a concave down shape is typically the easiest to deal with.
- Make certain not to chip the cladding on the fiber ends as they are fed through the two end collars.
- If the fibers start to slip off the collar halves:
  - Attach one or more of the top collar halves using only one mating screw.
  - Catch the first 2 or 3 threads only.
  - Place the top collar at a 90 degree angle to the bottom collar to allow easy access for fiber placement from above.

- Once all 36 fibers are in position, place the upper halves of the collars into position.
  - This may take a little time.
  - Ensure that the fibers are not twisted and run straight.
- With the collar halves all loosely attached, ensure that light guides extend past the two end collars by approximately the same amount.
  - Gently push the light guides as needed to align each with the proper overhang on the end collars.
- Using your thumb, index, and middle fingers pinch three sides of the fiber bundle into an even 5 x 6 rectangle near the middle collar (position 3).
- Keeping pressure on the bundle, evenly tighten the mating screws for the center collar.
- Torque the collar's mating screws to 10 foot-pounds.
- Working on one half of the bundle at a time, slide your three fingers along the fiber bundle from the tightened collar to the next collar.
  - Make certain that the fibers lay flat and are not twisted.
- Torque the next collar's mating screws to 10 foot-pounds.
- Repeat the previous two steps until all 5 fiber collars are tightened.

- Test to ensure no slippage of the center fibers by applying pressure to the center fiber of the bundle.
  - If slippage of fibers occurs, realign the fibers and torque the collars again up to 15 foot-pounds.
- Remove the SciFi cutting collar from the storage box and affix it to the straightening plate.
- Perform a final check to ensure all components are secure and straight.
- Insert the straightening plate into the heat treating pipe.
  - Start by donning safety glasses and gloves.

    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - If the level is above the mark on the tube then open the drain valve until the level is below the mark. At this point close the drain valve and proceed to the next step.
        - If the level is below the mark, proceed to the next step.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is inserted.
    - Insert the straightening plate.
        - Pay particular attention to ensure that the collars do not come in contact with the pipe which might cause damage or misalignment.
    - Make certain that the straightening plate is seated fully on the bottom of the tube.
    - Securely close the top cap.
- Open the top vent valve.
- Turn the tube vertical.
- Slowly open the fill valve.
    - Fill the tube until air no longer comes from the vent.
    - At this point close the vent valve.
    - Air may get trapped in the level indicator.
        - Simply squeeze the tube until the bubbles are removed.
- Close the two valves leading to the level indicator.
- Keeping the fill valve on, check for leakage from the top cap. Tighten as needed.
- Close the fill valve.
- Open the inlet and outlet valves to the pipe.
- Close the inlet and outlet valves to the heat treating tank.
- Perform a second check of the valve lineup.
- Begin the LabView program for “Fiber Straightening”.
- Once the program has finished wait until the water temperature is below 150ºF to begin the following steps.
- Remove the straightening plate from the heat treating pipe.
    - Start by donning safety glasses and gloves.

    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - First open the drain valve then open the vent valve on top of the pipe. Keep the drain valve open until the level is below the mark on the level indicator then close the drain valve.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is removed.
    - Slowly remove the straightening plate, making certain to minimize splashing of the hot water.
    - Place the straightening plate on the bundling table.
    - Re-cap the pipe, remove the pipe lock, return the pipe to the vertical position, and relock the pipe.
    - Ensure that the pipe is securely locked in the vertical position.
- Remove all collars from the straightening plate and set aside.
- Dry the collars and optical fibers using paper towels.
    - To minimize lint: use a tapping instead of wiping motion.
- Visually inspect the exposed fibers for cracks and crazing.
    - If defects are noted, set aside and inform the lead technician.
- Wrap the fiber bundles and collars with lint-free cloths and place in the intermediate storage box.
- Dry the straightening plate and place on its designated storage shelf above the bundling table.

3. Fiber Fine Cut

3.1 Overview

The optical fibers used for the tagger microscope are 2 mm square multi-clad fibers. These fibers consist of a polystyrene core surrounded by two layers of cladding one made from acrylic and the other from fluor-acrylic material. During construction of the tagger microscope special care must be taken to minimize/prevent the cladding from flaring away from the core. This is accomplished by the types of equipment used and the procedures that are carried out during construction. One such procedure that reduces cladding damage is detailed below.

3.2 Procedures

- Remove the bundled fibers from the intermediate storage box and place on the bundling table.
- Remove the lint-free cloths and hang on the wire above the table to dry.
- For the light guides:
    - Wrap a thin layer of plastic wrap between the collars.
    - Use a small strip of duct tape to hold the plastic in place. Ensure that the tape does not come in direct contact with the fibers.
- The fibers are now ready for the Physics machine shop to cut the fibers.
    - The fibers will be cut to within 0.019 inch from the surface of the end collars.
    - The end-mill will rotate at 1500 rpm.
    - Compressed air will be used throughout the cutting process to remove debris and prevent fouling out the cutting surface.
    - Three slow passes will be taken to cut the fibers.
    - The two cutting passes in which the cutting tool extends past the edge of the fiber bundle will be orientated so that the cutting tool rotates towards the center of the bundle. Thus the fibers that are being cut always push against other fibers and therefore fiber deflection is minimized leading to minimal cladding flare.
- Upon completion of the cutting in the machine shop, the fibers will be immediately returned to the construction lab.
- Once cut fibers are returned the fibers are to be cleaned.
    - Start by carefully removing the plastic from around the light guides and discard.
    - Remove all collars and set aside.
    - Move the loose fibers to a location on the table directly in front of you.
    - Clean the area of the table across from you using ethyl alcohol and a lint-free cloth. This area will be utilized for temporary storage of the cleaned fibers.
    - Using a lint-free cloth dampened with ethyl alcohol and start from the center of each fiber wiping to the end.
        - Make certain to extend fully past the end of the fiber and not to drag the cloth back against the end of the fiber as this may cause the cloth to snag on the fiber and result in separation of cladding from core.
    - Repeat the previous step as many times as necessary, while using different sections of the cloth to ensure that each fiber is clean.
    - Set each clean fiber in the designated “clean area” and continue to clean additional fibers until all have been cleaned.
- Visually inspect the clean fibers for damage.

    - Set aside damaged fibers and inform lead technician.
- All fibers that pass inspection are to be placed in the clean fibers bin of the intermediate storage box.
- Using the same equipment used to clean the fibers, clean the collars that were previously set aside.
- Store the clean collars in the appropriate location.
- Clean the fiber bundling table.

4. Individual Fiber Segment Polishing

4.1 Overview

The ends of each fiber must be polished to a mirrored finish. This allows the greatest amount of light transmission through the end of the fiber. The initial polishing process is performed prior to painting, since a polished fiber-end facilitates paint splatter removal. The following steps will be repeated following painting and whenever the technician deems it necessary.

4.2 Procedures

- Place the polishing plate on the fiber bundling table with the Velcro side against the table.
- Securely tape three sheets of copier paper to the top side of the polishing plate.
    - Make certain that the paper lies completely flat.
- Attach the polishing plate to the Velcro mounted on the side of the storage cabinet adjacent to the bundling table.
    - The polishing plate should mount flush to the table surface.
    - Note: the Velcro is positioned so that the plate may be rotated by 90 degree increments to utilize the entire copier paper surface during polishing.
- For each fiber segment (either SciFi or light guide) select one end to be highly polished.
    - Only one end of each segment will need to be polished since the other end is to be melted during the fiber splicing process.
    - When selecting which fiber-end to highly polish, consider the following:
        - Look for separation between the cladding and core, since this might be magnified by the polishing motion.
        - The heat of fusing might help re-adhere the flared cladding.
        - Flared cladding often has a rainbow discoloration on the surface of the cladding.
- Remove debris from the “splicing-end” of the fiber segment.
    - Grip the end of the fiber that will not be highly polished (splicing-end)

between the middle of your index finger and the pad of your thumb allowing about 1/8 of an inch to protrude past your fingers.
    - Press the fiber-end gently against the surface of the paper while maintaining the fiber length orthogonal to the paper surface.
    - Using a slow circular motion, make TWO rotations of the fiber-end on the copier paper.
        - Make sure to maintain the fiber the fiber perpendicular to the paper at all times. This will minimize rounding of the fiber-ends during polishing.
        - This will help to clean the debris from the fiber-ends prior to splicing and help to minimize contamination in the splicing joint.
- Polish the non-splicing end ("free-end") of each fiber segment.
    - Grip the free-end of the fiber securely between the middle of your index finger and the pad of your thumb allowing about 1/8 of an inch to protrude past your fingers.
    - Press the fiber-end gently against the surface of the paper while maintaining the fiber length orthogonal to the paper surface.
    - Using a slow circular motion, polish the fiber-end.
        - Make sure to maintain the fiber the fiber perpendicular to the paper at all times. This will minimize rounding of the fiber-ends during polishing.
    - After awhile the paper will become smooth and its polishing properties will become reduced. When this occurs start to slowly move to another portion of the paper.
    - When the bottom portion of the polishing paper becomes smooth, rotate the polishing plate 90 degree to expose a fresh portion of paper.
    - Once the complete surface area of the polishing paper has been used the top sheet may be removed to expose the under sheet.
        - Note: maintain at least two (and no more than 4) sheets of paper on the polishing plate at a time. Too few or too many sheets can result in possible cladding damage.
    - Continue polishing until a mirrored surface is achieved.
- Once both ends of the fiber segments have be processed, gently wipe the fiber with a lint-free cloth and then use compressed air to remove remaining debris.
    - As with the previous fiber cleaning technique, the fibers are to be wiped in the direction from the center to the end and past to prevent catching the cloth on the cladding.
    - The compressed air should never be directed onto the fiber "end-on", as this may cause cladding flaring.
- At this point, the fibers are to be returned to the appropriate bin of the

intermediate storage box.

- Use a vacuum hose and damp cloth to clean the bundling station of fiber debris.

5. Fusing Fibers

5.1 Overview

The joint between the SciFi and the light guide is one of the most critical points in the construction of the tagger microscope. Prior attempts to glue this joint with epoxy proved to be mechanically unreliable. A splicing unit has been procured from MSU and retrofitted for use with square fibers. Special order glass ferrules are used to maintain the fibers shape while the union between the SciFi and light guide are heated to the melting point. There are several dangers inherent to this type of procedure (i.e. flash burns to the eye, burns to the skin); therefore, numerous safety procedures and precautionary measures have been implemented to protect personnel and equipment.

5.2 Procedures

- Don protective equipment: powder-free gloves and long sleeves (or a lab coat).
- Power up the splicer and compressor by turning the splicer's power strip on.
- Start the exhaust fan.
- Inspect the splicing unit:
    - Check that the top sliding collar and compression block move smoothly and unencumbered.
    - Check for cracks in the glass ferrules.
    - Verify all peripheral equipment is in working order.
    - Note any discrepancies to the lead technician prior to proceeding with fusing of fibers.
- With the splicing collars open, place a clean, straight, cut SciFi in the bottom glass ferrule. Make sure that the fiber is butted up against the collar stop on the right-hand side.
- Place a clean, straight, cut light guide in the slot of the wooden guide used in the rough cutting process of the fiber.
    - This slot acts as a guide to help maintain the long length of light guide in-line with the glass ferrule.
- Place the end of the light guide closest to the splicer into the bottom glass ferrule and place it in contact with the SciFi. Make certain that both fibers are seated firmly in the ferrule and are as far to the right as possible (e.g. against the collar stop).
- Loosely hold the light guide in place while moving the top collar down so that it comes in contact with the bottom collar.

- Check to make sure that both fibers are seated properly.
- Turn down the protective light shield.
- Depress both start buttons to start the splicing unit.
- After the fusing cycle has stopped, slowly remove the fused fiber.
    - Note: be aware that some equipment may still be hot enough to cause burns, use caution.
- Visually inspect the fused joint, paying particular attention to look for:
    - Insufficiently fused fibers.
    - Air bubbles in the fused joint.
    - Excessive bubbling (boiling off) of the cladding.
- Next perform a comparison test.
    - Hold the newly fused fiber next to the control sample and note the intensity of light from each fiber-end.
        - If the newly fused fiber looks dimmer than the control fiber, set it aside for further testing and place the rubber-band tag labeled "?" around the group.
        - Inform the lead technician.
- The fibers that pass inspection are to be cleaned.
    - Using a lint-free cloth dampened with ethyl alcohol and start from the center of each fiber wiping to the end.
        - Make certain to extend fully past the end of the fiber and not to drag the cloth back against the end of the fiber as this may cause the cloth to snag on the fiber and result in separation of cladding from core.
    - Repeat the previous step as many times as necessary, while using different sections of the cloth to ensure that each fiber is clean.
- Set each clean fiber in the designated "fused fiber - clean area" bin of the intermediate storage box.
- Repeat the steps of section 5.2 until at least enough fiber pairs have been fused to construct a full complete bundle (minimum 30).

6. Single Fiber Testing

6.1 Overview

After enough fiber pairs have been fused to construct a bundle, manufacturing must temporarily pause to test the reliability of the aforementioned fusing process. In order to test the overall quality of the fusing phase, all questionable and at least 15% of the other fused fibers must be tested against a reference fiber.

6.2 Procedures

- Don a clean pair of powder-free gloves.
- Take the questionable fibers from the step 5 (fiber fusing) marked with the

rubber-band tag labeled "?" around the group.

- Randomly select at least 15% of the remaining fibers and place the rubber-band tag labeled "random" around the group.
- Take all the fibers to the table next to the testing station (dark box) located in the clean room of PB-402 and cover with the dark cloth.
    - Make certain to keep the questionable fibers separated from the randomly selected ones.
- Begin by filling out the basic information on the next spreadsheet in the sequence (i.e. bundle number, number of questionable fibers, etc.).
    - It is important to maintain proper "book-keeping" here, so that we are able to correctly reference back to this information after construction has completed.

NOTE: Every testing session begins with the use of a reference fiber. The steps that follow will be repeated until all fibers listed above (e.g. "questionable" and "random") have been tested.

**First begin with a reference fiber, then complete a test on all questionable fibers, and finish up by testing the randomly selected fibers. **

- Open the front panel of the dark box.
    - Start by removing the Velcro attached to the front panel and attaching it to the base of the dark box using the small Velcro strips attached on the backside of the cloth.
        - The light seal for the edges of the front panel consist of the Velcro strips attached to a thick cloth with one mating to the front panel and the other to the base of the dark box.
    - Once the top and side Velcro pieces have been removed from the front panel simply grasp the two panel handles and put to unseat the panel.
        - The front panel is hinged at the bottom and therefore the bottom Velcro strip need not be removed.
    - Rotate the front panel 180 degrees about its hinges and allow it to hang while working inside.
- With the front panel open, use the string attached to the back wall to tie back the center dark cloth.
- Next remove the mini-chimney on the left-hand-side of the bottom of the dark box base.
- Once out of the box, remove the clamp from the top of the mini-chimney and set aside.
- Paying particular attention not to mar the end of the fiber, insert the SciFi end of the fiber into the mini-chimney's slot. Start with the fiber-end angled slightly up and first introduce the section of fiber that is closest to the fiber

center. Now using a tilting action, guide the rest of the fiber into place until the fiber-end is seated in the slot. Once the fiber is in place secure using the clamp previously removed.

  - Ensure that the fiber-end is flush to the mini-chimney surface by gently sliding it into place before securing.
  - Note: a piece of clean copier paper can be a useful barrier between the technician's gloved finger and the fiber-end to prevent snagging of their glove while they ensure that the fiber is flush.

- Reinsert the mini-chimney onto the platform on the base of the dark box and secure using the wing-nuts previously removed.
  - The platform for the test source is on a movable track; therefore special care must be taken to ensure that the fiber is not pulled out of either mini-chimney during the next few steps.
  - Note: the tracked source allows for small variations in overall fiber lengths.
- Next remove the mini-chimney on the right-hand-side of the bottom of the dark box base.
- Once out of the box, remove the clamp from the top of the mini-chimney and set aside.
- Again, paying particular attention not to mar the end of the fiber, insert the light guide end of the fiber into the mini-chimney's slot. Start with the fiber-end angled slightly up and first introduce the section of fiber that is closest to the fiber center. Now using a tilting action, guide the rest of the fiber into place until the fiber-end is seated in the slot. Once the fiber is in place secure using the clamp previously removed.
  - Ensure that the fiber-end is flush to the mini-chimney surface by gently sliding it into place before securing.
  - Note: a piece of clean copier paper can be a useful barrier between the technician's gloved finger and the fiber-end to prevent snagging of their glove while they ensure that the fiber is flush.
- Reinsert the mini-chimney into the base of the dark box and secure using the wing-nuts previously removed.
  - The platform for the test source is on a movable track; therefore special care must be taken to ensure that the fiber is not pulled out of either mini-chimney.
- Verify that the fiber-ends are secure and flush to their respective chimney faces.
- Check for loose wiring and misaligned components.
  - Fix any problems and inform the lead technician so they may track any trends and deal with them accordingly.
- Remove the string holding the dark cloth to the back wall and let it drape over the center of the light guide without extending past the edge of the box

or covering the weather stripping used to help with the light tight seal.

- Close the front panel of the dark box.
    - Grasp the two handles and rotate the panel into the vertical position.
    - As you rotate the panel, inspect the foam weather stripping along the perimeter of the front panel for damage. Replace sections if necessary since this helps to provide a light tight seal during testing.
    - The front panel has several cabinet door catches which help hold it securely in place. Each catch requires between 3 to 6 pounds of force to close, so firmly grasp the back of the dark box as you seat the front panel into its closed position.
    - With the front panel firmly seated in place, attach the previously removed Velcro back onto the front panel.
        - Ensure that there is a smooth and continuous seal.
- Commence the LabView program for light transmission test.
- Record the data on the spreadsheet.
    - Make certain to specify if the fiber is a reference, questionable, or random fiber.
- Repeat the previous steps until all fibers for this testing session have been examined.
- If a tested fiber is outside of the listed specifications (not within 15% of the reference fiber), then place a handwritten label on that fiber near the end opposite the SciFi end stating the reference valve for that batch of testing and the fibers out-of-spec value.
    - In form the lead technician, and set aside for retesting.
- Use a rubber-band label that indicates the bundle number and the words "QA Pass" on it to group the passing fibers all together.
- Place all fibers that have passed the quality check in the bin of the intermediate storage box labeled "QA Pass".
- Place the labeled fibers that failed testing into the intermediate storage box compartment labeled "Failed".
- The failed fibers will be visually inspected in an attempt to determine why they failed.
    - If no explanation for failure is found or an attempt is made to fix the fiber, then it will be retested using the aforementioned steps.
    - If the fiber fails once again then it will be discarded.
- Once testing is complete and all fibers have either passed or been discarded, the test data recorded on the spreadsheet will be recorded electronically using Excel and stored on the UConn PAN webpage.

7. Fiber Cleaning

7.1 Overview

Cleanliness is important throughout the construction process. Of particular concern is during the painting process when debris may become permanently embedded into the individual fibers. Additionally, oils from the technician's skin may diminish the bond between the paint and the fiber.

7.2 Procedures

- Ensure that the table adjacent to the dark box is clean.
- Don a clean pair of powder-free gloves.
- Clean the fibers that have passed inspection in step 6 "Single Fiber Testing".
    - Using a lint-free cloth dampened with ethyl alcohol and start from the center of each fiber wiping to the end.
        - Make certain to extend fully past the end of the fiber and not to drag the cloth back against the end of the fiber as this may cause the cloth to snag on the fiber and result in separation of cladding from core.
    - Repeat the previous step as many times as necessary, while using different sections of the cloth to ensure that each fiber is clean.
- Set each clean fiber in the designated "To be Painted - Clean Fiber" bin of the intermediate storage box.

8. Fiber Painting

8.1 Overview

Optical crosstalk is a concern with closely packed fibers. An air gap between fibers is an excellent way to minimize the possibility of optical crosstalk, but for the tagger microscope's 17 closely packed fiber bundles this is not an option. Therefore, the individual fibers are painted in the section that comes in contact with other fibers.

8.2 Procedures

- Don a clean pair of powder-free gloves.
- Remove the cleaned fiber from the bin of the intermediate storage box labeled "To be Painted - Clean Fiber" and place on the painting station table.
- Cover the light guide end of each fiber.
    - Use a small piece of lint-free cloth to cover the end.
    - Wrap the fiber and cloth with a rubber-band to keep the cloth in place.
- Mix Titanium Oxide paint.
    - Thin with water as needed.
- Fill airbrush reservoir approximately ¾ full with paint.
- Use airbrush painter to apply a thin, even coat of paint to the straight section of fiber.
- Let dry 15 minutes.

- Inspect for uncoated areas and touch-up as necessary.
- Let dry 15 minutes.
- Perform end polishing steps to remove paint from the fiber-ends.
- Perform a final fiber inspection, looking for:
    - Uncoated areas.
    - Paint splatter on the fiber-ends.
    - Any damage to fiber or fiber joint during the painting process.
- Set aside all fibers that do not pass inspection.
    - For undercoated or end splattered fibers: perform the applicable steps listed above until the problem has been remedied.
    - For undercoated fibers: carefully measure the cross-sectional dimensions of the fiber every 3 inches and record on the paint station spreadsheet.
    - If the fiber exceeds the indicated dimensional tolerances, set aside for assessment by the lead technician.
    - If a fiber has been damaged during the painting process inform the lead technician and set the fiber aside.
        - It is at the lead technician's discretion whether the fiber can be salvaged or must be discarded.
- At least 20% of the fibers that pass inspection, whether initial or secondary, are to be tested at 4 locations to verify that the fiber's cross-sectional dimensions are within the allowable tolerances.
    - These measurements are to be record on the paint station spreadsheet.
    - If the fiber exceeds the indicated dimensional tolerances, set aside for assessment by the lead technician.
- All fibers that pass inspection are to be grouped together using a rubber-band label that indicates the bundle number.
- Place the grouped fibers into the bin of the intermediate storage box labeled "Painted Fibers".
- Place a label indicating the reason for the failure of a fiber on each failed fiber.
- Place all rejected fibers into the bin of the intermediate storage box labeled "Rejects".

9. Final Polishing

9.1 Overview

The ends of each fiber must be polished to a mirrored finish. This allows the greatest amount of light transmission through the end of the fiber.

9.2 Procedures

- Place the polishing plate on the fiber bundling table with the Velcro side

against the table.

- Securely tape three sheets of copier paper to the top side of the polishing plate.
    - Make certain that the paper lies completely flat.
- Adhere the polishing plate to the Velcro mounted on the side of the storage cabinet adjacent to the bundling table.
    - The polishing plate should mount flush to the table surface.
    - Note: the Velcro is positioned so that the plate may be rotated by 90 degree increments to utilize the entire copier paper surface during polishing.
- Remove the group of fibers from the bin of the intermediate storage box labeled "Painted Fibers".
- Remove the bundle label and set aside.
- Visually inspect the fiber free-ends.
    - Look for large gouges, chipped cladding, and paint splatter.
    - Report significant defects to the lead technician.
- Perform a final polishing of each fiber-end, if needed.
    - Grip the fiber securely between the middle of your index finger and the pad of your thumb allowing about 1/8 of an inch to protrude past your fingers.
    - Press the fiber-end gently against the surface of the paper while maintaining the fiber length orthogonal to the paper surface.
    - Using a slow circular motion, polish the fiber-end.
        - Make sure to maintain the fiber the fiber perpendicular to the paper at all times. This will minimize rounding of the fiber-ends during polishing.
    - After a while the paper will become smooth and its polishing properties will become reduced. When this occurs start to slowly move to another portion of the paper.
    - When the bottom portion of the polishing paper becomes smooth, rotate the polishing plate 90 degree to expose a fresh portion of paper.
    - Once the complete surface area of the polishing paper has been used the top sheet may be removed to expose the under sheet.
        - Note: maintain at least two (and no more than 4) sheets of paper on the polishing plate at a time. Too few or too many sheets can result in possible cladding damage.
    - Continue polishing until a mirrored surface is achieved.
- Once both ends of the fused fiber are polish, gently wipe the fiber with a lint-free cloth and then use compressed air to remove remaining debris.
    - As with the previous fiber cleaning technique, the fibers are to be wiped in the direction from the center to the end and past to prevent catching the cloth on the cladding.

    - The compressed air should never be directed onto the fiber "end-on", as this may cause cladding flaring.
- Grouped the cleaned fibers together using a rubber-band label that indicates the bundle number.
- Place the grouped fibers into the bin of the intermediate storage box labeled "To be bundled".
- Use a vacuum hose and damp cloth to clean the bundling station of fiber debris.

10. "Housekeeping" Step

10.1 Overview

In the foregoing steps there have been numerous places where fibers might have been rejected for various reasons. This can often lead to too few fibers to make a complete bundle. It is at this point in the construction process where we must pause and account for those loses in the overall fiber count. If too many fibers have been rejected in any of the previous step, as often will be the case, we may need to combine fibers from different bundles. This "house-keeping" step will allow for us to combine fibers from one bundle to another so that we may construct a full 5 x 6 bundle in the proceeding steps.

10.2 Procedures

- If no fibers were rejected.
    - Proceed directly to the fiber bundling step.
- If < 30 are present in a bundle, then:
    - Wait for the next bundle and transfer the required number, to make a full bundle, to the awaiting bundle.
    - Keep the bundle labeling number and record the quantity transferred and from which bundle in the electronic logbook.

11. Fiber Bundling

11.1 Overview

From this point forward the subsequent procedures are intended for the preparation of a usable 5 x 6 fiber bundle and therefore the notion of individual fiber strands will only be referred to in a context as it relates to the construction of a bundle. The construction of a complete bundle requires numerous steps which have been broken down here in a logical progression.

11.2 Procedures

- Note: The fiber bundling procedure requires 2 technicians.

- Clean the bundling station table.
- Set out:
    - 6 light guide collars.
    - Straightening plate.
    - Upper and lower halves of the offset-block.
- Don a clean pair of powder-free gloves.
- Remove the clean, painted fibers from the bin of the intermediate storage box labeled "To be bundled" and place on the bundling station table.
- Separate the two halves of 4 of the 6 light guide collars.
- Loosen the screws on the remaining 2 collars.
- Attach the collars to the straightening plate.
    - Note: the collars are to be mounted so that the vertical portions of the bottom halves are as close to the back of the straightening plate as possible. Placing the collars the other way will prevent access to tighten the lower mating screws by the straightening plate.
    - Start by screwing the two collars that have both halves still attached into positions 1 and 6 on the straightening plate.
    - Next screw the bottom halves of the remaining three collars into positions 2 – 5 on the straightening plate.
        - The bottom half of a collar is the ones with male threads, not through holes at the mating surface of the two halves.
- Carefully feed the fibers one-by-one through the two end collars allowing the center section of fiber to lie on the three bottom collar halves.
    - The SciFi end of the fiber should be at the position 6 end of the straightening plate.
    - Make certain not to mar the fiber ends as they are fed through the two end collars.
    - If the fibers start to slip off the collar halves:
        - Attach one or more of the top collar halves using only one mating screw.
        - Catch the first 2 or 3 threads only.
        - Place the top collar at a 90 degree angle to the bottom collar to allow easy access for fiber placement from above.
- Once all 30 fibers are in position, place the upper halves of the collars into position.
    - This may take a little time.
    - Ensure that the fibers are not twisted and run straight.
- With the collars halves all loosely attached, affix the end-block against the outer edge of the collar in position 6 (SciFi end).
- Gently push the light guide end of the fibers, so as to mate the SciFi end of each fiber against the surface of the end-block.
- Maintaining gentle pressure on all the light guide fiber ends, have a second

technician slowly and evenly tighten down the top half of the collar in position 6 (SciFi end).

- Continue to tighten the successive collars into place while maintaining pressure to the fiber end.
    - As the collars are tightened, continually ensure that the fibers are lying flat and not pinched between collar halves.
- Torque the collar screws to 10 foot-pounds.
- Test to ensure no slippage of the center fibers by removing the end-block and applying pressure to the center fiber of the bundle.
    - If slippage of fibers occurs, realign the fibers and torque the collars again up to 15 foot-pounds.
- Perform a final check to ensure all components are secure and straight.

12. Offsetting Bending

12.1 Overview

As a result of the small beta angle and optical enclosure design, there is a large portion of the optical fiber that would normally be in the direct path of the electrons. By offsetting the light guide soon after the SciFi section, we are able to reduce the amount of fiber exposed to the electrons' trajectory.

12.2 Procedures

- Insert the straightening plate into the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - If the level is above the mark on the tube then open the drain valve until the level is below the mark. At this point close the drain valve and proceed to the next step.
        - If the level is below the mark, proceed to the next step.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is inserted.
    - Insert the straightening plate.
        - Pay particular attention to ensure that the collars do not come

in contact with the pipe which might cause damage or misalignment.
    - Make certain that the straightening plate is seated fully on the bottom of the tube.
    - Securely close the top cap.
- Open the top vent valve.
- Turn the tube vertical.
- Slowly open the fill valve.
    - Fill the tube until air no longer comes from the vent.
    - At this point close the vent valve.
    - Air may get trapped in the level indicator.
        - Simply squeeze the tube until the bubbles are removed.
- Close the two valves leading to the level indicator.
- Keeping the fill valve on, check for leakage from the top cap. Tighten as needed.
- Close the fill valve.
- Open the inlet and outlet valves to the pipe.
- Close the inlet and outlet valves to the heat treating tank.
- Perform a second check of the valve lineup.
- Begin the LabView program for "Fiber Preheating".
    - This will raise the water temperature to 120°F.
    - 120°F will be maintained as the water is circulated to preheat the fibers.
    - Preheating the fibers minimizes the chances of crazing and helps to reduce internal stresses in the fibers.
- Once the program has finished remove the straightening plate from the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - First open the drain valve then open the vent valve on top of the pipe. Keep the drain valve open until the level is below the mark on the level indicator then close the drain valve.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the

straightening plate is removed.
    - Slowly remove the straightening plate, making certain to minimize splashing of the hot water.
    - Place the straightening plate on the bundling table.
    - Re-cap the pipe, remove the pipe lock, return the pipe to the vertical position, and re-engage the pipe lock.
- Ensure that the pipe is securely locked in the vertical position.
- Position the straightening plate so that the screws maintaining the collars' position are down against the bundling table.
- Evenly loosen the mating screws for all the light guide collars EXCEPT the TWO closest to the SciFi end.
- Position the straightening plate so that the screws maintaining the collars' position are exposed.
- Remove the screws holding the two collars in positions 5 & 6 (SciFi end) in place.
- While lifting the bundle end away from the straightening plate, insert the bottom half of the offset collar.
    - Secure into place using screws through position 5 & 6's holes.
- Next place the top half of the offset collar into place and catch 2 or 3 threads through the elongated holes in the straightening plate.
    - Make certain that only a slight pressure is applied to the fiber bundle at this point in the offset procedure.
- Affix the temporary top plate to the top half offset collar.
    - This plate applies a slight downward force to the top of the light guide collar.
    - It also prevents the bundle from catching on the heat treating pipe when the straightening plate is inserted.
- Reinsert the straightening plate into the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - If the level is above the mark on the tube then open the drain valve until the level is below the mark. At this point close the drain valve and proceed to the next step.
        - If the level is below the mark, proceed to the next step.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact

with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is inserted.
    - Insert the straightening plate.
        - Pay particular attention to ensure that the collars do not come in contact with the pipe which might cause damage or misalignment.
    - Make certain that the straightening plate is seated fully on the bottom of the tube.
    - Securely close the top cap.
- Open the top vent valve.
- Turn the tube vertical.
- Slowly open the fill valve.
    - Fill the tube until air no longer comes from the vent.
    - At this point close the vent valve.
    - Air may get trapped in the level indicator.
        - Simply squeeze the tube until the bubbles are removed.
- Close the two valves leading to the level indicator.
- Keeping the fill valve on, check for leakage from the top cap. Tighten as needed.
- Close the fill valve.
- Open the inlet and outlet valves to the pipe.
- Close the inlet and outlet valves to the heat treating tank.
- Perform a second check of the valve lineup.
- Begin the LabView program for "Begin Fiber Offset".
    - This will raise the water temperature to 140°F.
    - 140°F will be maintained as the water is circulated to heat and start to shape the fibers.
- Once the program has finished remove the straightening plate from the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - First open the drain valve then open the vent valve on top of the pipe. Keep the drain valve open until the level is below the mark on the level indicator then close the drain valve.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.

    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is removed.
    - Slowly remove the straightening plate, making certain to minimize splashing of the hot water.
    - Place the straightening plate on the bundling table.
    - Re-cap the pipe, remove the pipe lock, return the pipe to the vertical position, and re-engage the pipe lock.
- Ensure that the pipe is securely locked in the vertical position.
- Position the straightening plate so that the screws maintaining the collars' position are exposed.
- Apply a steady force to the fiber bundle (towards the straightening plate and the other offset collar) as the screws to upper offset collar are tightened.
- Reinsert the straightening plate into the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - If the level is above the mark on the tube then open the drain valve until the level is below the mark. At this point close the drain valve and proceed to the next step.
        - If the level is below the mark, proceed to the next step.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is inserted.
    - Insert the straightening plate.
        - Pay particular attention to ensure that the collars do not come in contact with the pipe which might cause damage or misalignment.
    - Make certain that the straightening plate is seated fully on the bottom of the tube.
    - Securely close the top cap.
- Open the top vent valve.
- Turn the tube vertical.
- Slowly open the fill valve.

    - Fill the tube until air no longer comes from the vent.
    - At this point close the vent valve.
    - Air may get trapped in the level indicator.
        - Simply squeeze the tube until the bubbles are removed.
- Close the two valves leading to the level indicator.
- Keeping the fill valve on, check for leakage from the top cap. Tighten as needed.
- Close the fill valve.
- Open the inlet and outlet valves to the pipe.
- Close the inlet and outlet valves to the heat treating tank.
- Perform a second check of the valve lineup.
- Begin the LabView program for "Intermediate Fiber Offset".
    - This will raise the water temperature to 160°F.
    - 160°F will be maintained as the water is circulated to heat and start to shape the fibers.
- Once the program has finished remove the straightening plate from the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - First open the drain valve then open the vent valve on top of the pipe. Keep the drain valve open until the level is below the mark on the level indicator then close the drain valve.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is removed.
    - Slowly remove the straightening plate, making certain to minimize splashing of the hot water.
    - Place the straightening plate on the bundling table.
    - Re-cap the pipe, remove the pipe lock, return the pipe to the vertical position, and re-engage the pipe lock.
- Ensure that the pipe is securely locked in the vertical position.
- Position the straightening plate so that the screws maintaining the collars' position are exposed.
- Remove the temporary top plate from the upper offset collar and set aside.

- Apply a steady force to the fiber bundle (towards the straightening plate and the other offset collar) as the screws to upper offset collar are tightened.
- At this point, insert the offset alignment screws the side of the lower offset collar and catch a few threads in the upper offset collar.
- Maintaining a steady force on the fiber bundle (towards the straightening plate and the other offset collar), alternately tighten the upper offset collar screws and the alignment screws.
    - Continue to slowly tighten these screws in succession until the two offset collars are completely mated.
    - Make certain that the light guide collar is cleanly seated in the notch provide at the end of the lower offset collar.
- With the offset collars completely in place, begin the LabView program for "Final Fiber Offset".
    - This will raise the water temperature to 180ºF.
    - 180ºF will be maintained for 15 minutes as the water is circulated to heat and shape the fibers.
    - After 15 minutes of maintained heat the heater is secured and the circulating pump will continue to run until the water temperature has cooled to 100ºF.
- Once the program has finished remove the straightening plate from the heat treating pipe.
    - Start by donning safety glasses and gloves.
    - Ensure that the liquid level is low enough so that none spills out.
        - Open the two valves leading to the level indicator.
        - Give the tube a gentle squeeze in the middle to ensure proper flow.
        - First open the drain valve then open the vent valve on top of the pipe. Keep the drain valve open until the level is below the mark on the level indicator then close the drain valve.
    - While keeping the pipe vertical, remove the top cap and set aside.
    - With the pipe still vertical check to see that the water level is actually where the indicated had shown. If not, open the drain valve until below the marked level.
    - Remove the pipe lock and slowly tilt the pipe until it comes in contact with the stop.
    - Re-engage the pipe lock to maintain its orientation while the straightening plate is removed.
    - Slowly remove the straightening plate, making certain to minimize splashing of the hot water.
    - Place the straightening plate on the bundling table.
    - Re-cap the pipe, remove the pipe lock, return the pipe to the vertical position, and re-engage the pipe lock.

- Ensure that the pipe is securely locked in the vertical position.
- Place the straightening plate on the fiber bundling table.
- Drain a dark cloth over the straightening plate to minimize light exposure and allow the bundle to cool to room temperature.
- Once cooled remove the protective cloth and position the straightening plate so that the screws maintaining the collars' position are exposed.
- Remove all screw holding the offset collars in place.
- Next remove the screws holding the light guide collars to the straightening plate.
- Wrap the bundle in dry lint-free cloths and place in the intermediate storage box bin labeled "Offset Fibers".
- Dry the plate and offset collars and store in their designated areas on the shelves above the fiber bundling station.

13. Bundle Drying

13.1 Overview

To accelerate the drying of a bundle after heat treating we use a dehumidifier.

13.2 Procedures

- Ensure the work table in the clean room is clean.
- Don powder-free gloves.
- Move the wrapped bundle from the intermediate storage box bin labeled "Offset Fibers" to the work table in the clean room.
- Carefully remove the three light guide collars closest to the SciFi end of the bundle.
- Gently spread the individual fibers slightly apart to allow airflow.
- Place the bundle in the drying box in the clean room.
- Cover the drying box with a dark cloth.
- Ensure that the exhaust port for the dehumidifier is properly aligned to blow into the drying box.
- Start the dehumidifier and the timer.
- After 2 hours of drying, remove the bundle from the drying box.
- Check for moisture between the fibers.
    - If moisture is present, reinsert in the drying box for 1 additional hour.
    - After 1 hour, recheck for moisture.
        - If moisture is still present, use a dry lint-free cloth to gently dry the moisture between the fiber layers.
        - Then reinsert in the drying box for 1 additional hour.
- Once the bundle is deemed moisture free, reinstall the light guide collars previously removed.
- Place the bundle in the intermediate storage box bin labeled "To be glued".

14. Bundle Gluing

14.1 Overview

The bundles are mounted on "popsicle sticks" which provide the structural support and positioning of the bundles. The following procedure describes how the popsicle sticks are glued to the bundle. In addition to affixing the popsicle stick to the bundle, the portion of light guides that will be inside the optical enclosure are glued together to form a 5x6 rectangle. This permits an organized egress of the more than 500 optical fibers from the back of the upper enclosure.

14.2 Procedures

- Note: Bundle gluing requires 2 technicians.
- Don powder-free gloves.
- Remove the gluing station from its storage location and place near the corner of the working table.
    - The gluing station should be orientated so that the bundle will lay on the table parallel to the long side of the table with SciFi end of the gluing station at the edge of the short side of the table.
- Tape a stack of 2 to 3 sheets of paper alongside the gluing station.
    - This stack will allow the gluing technician to clean the end of the syringe by gently brushing it along the paper.
- Line the surface of the gluing station with aluminum foils.
    - Make certain not to tear the foil.
    - Lay all pieces flat.
    - Ensure all corners fit snugly.
    - Using a razor knife carefully cut out a precise hole for the bolt of the popsicle stick.
    - Make sure to leave enough of a foil overhang on one side to cover the top and completely encapsulate the bundle during the final stages of gluing.
- Use the engraver to etch the bundle number into the front-end and underside of the popsicle stick.
    - Perform this task outside the clean room.
    - Once engraving is complete, clean the popsicle stick with ethyl alcohol and a clean lint-free rag.
- Place the assembled popsicle stick into position over the aluminum foil.
- Remove the "To be glued" bundle from the intermediate storage box and place on the working table in the clean room.
- Carefully remove the three light guide collars closest to the SciFi end of the bundle.
- Gently spread the individual fibers slightly apart to ensure free movement.

- Set the fiber bundle into the gluing station.
- Once firmly in place secure the end of the bundle furthest from the SciFi's onto the gluing station using the clamp provided.
- Cover the bundle and gluing station with a dark cloth.
- Don protective equipment: gloves and goggles.
- Following the manufacturer's instructions, mix a 25 ml batch of BC-600 epoxy.
- Once mixed, immediately place the epoxy in a vacuum bell jar and draw a vacuum for two minutes.
- Remove the epoxy from the bell jar and fill a 5 ml syringe with BC-600.
    - First remove the clean syringe from its wrappings.
    - With the protective cap still on remove the needle from the syringe by twisting counter clockwise.
    - Once the needle is removed, depress the plunger completely.
    - Insert the end of the syringe into the epoxy and withdraw the plunger.
        - Make sure to keep the syringe tip submerged at all times to minimize the introduction of air.
    - After the plunger has been fully withdrawn and the syringe is full of BC-600, remove the syringe tip from the epoxy reservoir and reconnect the needle.
    - With the needle seated firmly into place and the protective cap still on, use a cloth to remove accumulated epoxy on the exterior of the syringe.
- Set aside the reservoir of epoxy for disposal later once it has cured.
- Remove the dark cloth from the bundle and have one technician ("bundle-technician") stand alongside the gluing station with the light guide end pointing behind him.
- The bundle-technician will lift all but one row of fibers, exposing the section of the bottom row that will be glued.
- The other technician ("gluing-technician") will apply a thin S-shaped pattern of BC-600 across the top of the bottom row.
    - Make sure not to scrape the paint from the fibers while applying the epoxy.
    - The S-shape should be a frequent pattern to provide a sufficient, yet not excessive, amount of epoxy.
- Once sufficient epoxy has been applied to the first row of fibers, the bundle-technician will slowly lower the next row of fibers.
- The gluing-technician will then again apply an S-shaped coat of epoxy to this row.
- The bundle & gluing technicians will repeat the aforementioned process until the 5th and last row has been placed on top.
    - No epoxy is applied directly to the top row of fibers.

- With all bundle rows in place, the aluminum foil is folded over the top of the bundle.
- The top section of the gluing station is set in place and loosely tightened down.
- At this point in the procedure a visual inspection is performed to check for misalignment and possible problems.
    - Make corrections to the setup as necessary.
- Alternately adjust the different screws on the gluing station to increase the pressure applied to the top and side of the bundle.
- As adjustments are made, wipe off excess epoxy that seeps out from between the bundle.
    - Make certain not to wipe epoxy across the face of the SciFi ends.
    - If epoxy gets on the surface of the SciFi ends, use a lint-free cloth dampened with ethyl alcohol to wipe clean.
- Cover the gluing station with a cardboard box designed to block out light and the rest of the bundle with the dark cloth.
- Recap the needle of the syringe and dispose of the used syringe in the appropriate receptacle.
- Continue to check for seepage during at least the first hour of curing.
- Dispose of the epoxy reservoir once it has cured fully.
- Let the epoxy cure at room temperature for at least 12 hours.
- Remove all the coverings.
- Loosen the adjustment screws and carefully remove the bundle.
- Peel away the aluminum foil and visually inspect the glued bundle for defects.
- At 3 evenly spaced locations starting from the end of the offset, measure the cross-sectional dimensions of the bundle and record them on the gluing spreadsheet.
- Measure the width of the bundle at the beginning, middle, and end of the popsicle stick and record the data.
- Measure the height of the bundle at the beginning and end of the popsicle stick and record the data.
- Verify that the bundle dimensions are within the required specifications.
    - If out-of-spec, set the bundle aside and inform the lead technician.
- Use a Sharpie pen to fill in the engraved bundle number on the bottom and front of the popsicle stick.
- Place the glued bundle in the “To be bent” bin of the intermediate storage box.
- Clean the gluing station of epoxy and place it back on the storage shelf.
- Update the data record online.

15. Bundle Bending

15.1 Overview

The bundle bending step affords several benefits in the construction process. Shaping of the bundle not only helps to relieve internal stresses, but also allows for easier manipulation during installation and helps to sustain the shape required by the two enclosure design of the tagger microscope. Ideally this step should be performed at the end of the workday. This will minimize light exposure to the fiber bundle when the bending unit cover is removed for the 6 to 8 hour cooling period.

15.2 Procedures

- This procedure requires two technicians.
- Set out on the bundling table:
    - Base-plate.
    - 2 chimney-plates.
    - 5 light guide collars.
    - 8 guide-chimneys.
    - 2 chimneys.
    - Protective cloth.
    - A single clean sheet of paper.
    - 4 cylindrical spacers and associated bolts.
    - 2 braces and associated bolts.
- Don powder-free gloves.
- Separate the two halves of the 5 light guide collars.
- Attach the collars to the base-plate.
    - Start by screwing the bottom halves of the light guide collars into positions 1 – 5 on the base plate.
        - The bottom half of a collar is the ones with male threads, not through holes at the mating surface of the two halves.
- Remove all 8 guide-chimney clamps and set aside for later use.
- Loosen the clamps on the 2 chimneys, but do not remove completely.
- Attach the 8 guide-chimneys to the 2 chimney-plates (4 on each).
    - Attach to positions 2 – 5 using screws.
    - The plate is etched to indicate which side to attach the chimneys to.
- Use the engraver to etch the bundle number into the end of the extension piece and two sides adjacent to the notched portion of the chimney.
    - Label one chimney with the bundle number followed by an “A” and the other with the bundle number followed by a “B”.
        - Example: 7A & 7B
    - Perform this task in an area away from the bundling station.
    - Once engraving is complete, clean the chimney with ethyl alcohol and a clean lint-free rag.
- Attach a chimney to each of the chimney-plates in position 1.

- Remove the fiber bundle from the “To be bent” bin of the intermediate storage box and carefully lay the fiber bundle onto the lower half light guide collars.
    - Make certain not to mar the fiber ends.
- Once the bundle is in position, place the upper halves of the collars into position.
    - This section of fiber has been glued so do not apply excessive force as it may result in cracking of the glue.
    - At this point about half of the fiber bundle should be extended past the base-plate
- Lightly tighten the top half of the collars into place.
    - Use your thumb and index finger to turn the allen-key during collar tightening.
    - This minimizes the chance of applying excessive force to the bundle.
    - The intent of these collars is to provide a guide for the glued section of fiber.
- Test to ensure there is no slippage of the bundle by gently wiggling different sections of the bundle.
    - If slippage of fibers occurs, realign the bundle and tighten the affected collars as stated above.
- Perform a final check to ensure all components are secure and straight.
- Take strips of paper and use them to separate the 6 different columns of fibers near the light guide end of the bundle.
- Making certain not to let the column separators slip out, flip the base-plate 180 degrees so that is laying face down on the bundling table with the light guide end of the bundle on the right-hand-side.
- Place a protective cloth over the chimney-plate “A”.
- Place the chimney-plate with the chimney labeled “B” face-up on the top of the chimney-plate already on the table (chimney side up).
- Starting with the separated column, not previously used, closest to the technician, place the individual fibers into the chimney slots.
    - Careful not to catch the cladding or mar the fiber end, slip the fibers into place in the designated slot of the chimney.
        - The fiber end should be flush with the side of the chimney.
        - Move the chimney-plate into position, as needed.
    - Ensure that the fiber is not twisted and lays flat onto all the guide-chimneys.
    - The fiber in the row closest to the bundling table will be in the first available slot positioned closest to the technician.
    - The fiber in the next row closest to the bundling table (one row away from the table) will be in the first available slot positioned closest to the technician (slot number 2, right next to the first fiber.

    - Continue this pattern until the 5 fibers of the column closest to the technician are in place.
    - Now move onto the next closest column to the technician and proceed as detailed above.
- Once the first 3 columns of fibers closest to the technician are in the chimney designated "A", tighten down the chimney clamp.
    - Torque to 10 foot-pounds, while ensuring that each fiber end mates flush with the surface of the chimney.
    - Use a sheet of paper to place between your gloved finger and fiber end to check if it is flush.
        - This allows the technician to gently rub back and forth to feel for protrusions of the fiber and minimize the possibility of marring the end.
- Inspect for fiber slippage.
    - If slippage occurs, re-align the fiber and torque the clamp down further to a maximum of 15 foot-pounds, if needed.
- With the chimney secure, tighten down the guide-chimney clamps to 10 foot-pounds.
    - Start with the guide-chimney closest to the chimney and work your way towards the SciFi end.
- Place the chimney-plate with the chimney labeled "A" face-up on the table (chimney side up).
- Starting with the separated column closest to the technician, place the individual fibers into the chimney slots.
    - Careful not to catch the cladding or mar the fiber end, slip the fibers into place in the designated slot of the chimney.
        - The fiber end should be flush with the side of the chimney.
        - Move the chimney-plate into position, as needed.
    - Ensure that the fiber is not twisted and lays flat onto all the guide-chimneys.
    - The fiber in the row closest to the bundling table will be in the first available slot positioned closest to the technician.
    - The fiber in the next row closest to the bundling table (one row away from the table) will be in the first available slot positioned closest to the technician (slot number 2, right next to the first fiber.
    - Continue this pattern until the 5 fibers of the column closest to the technician are in place.
    - Now move onto the next closest column to the technician and proceed as detailed above.
- Once the first 3 columns of fibers closest to the technician are in the chimney designated "A", tighten down the chimney clamp.
    - Torque to 10 foot-pounds, while ensuring that each fiber end mates

flush with the surface of the chimney.
    - Use a sheet of paper to place between your gloved finger and fiber end to check if it is flush.
        - This allows the technician to gently rub back and forth to feel for protrusions of the fiber and minimize the possibility of marring the end.
- Inspect for fiber slippage.
    - If slippage occurs, re-align the fiber and torque the clamp down further to a maximum of 15 foot-pounds, if needed.
- With the chimney secure, tighten down the guide-chimney clamps to 10 foot-pounds.
    - Start with the guide-chimney closest to the chimney and work your way towards the SciFi end.
- Carefully remove the protective cloth between the two chimney-plates.
- Bolt the two chimney-plates together using the 4 cylindrical spacers.
- Attach the 2 braces between the base & chimney-plates.
    - Adjust the bolts along the elongated holes of the base-plate, as needed, to maintain the fiber bundle as straight as possible.
- Attach the 4 threaded rods to the base-plate.
    - Each threaded rod is etched on the end with a number corresponding to its proper location on the base-plate.
- Ensure that the stabilizing cylinder is attached to one of the rods and is orientated to support the structure when the plates are placed on their side.
- Don safety glasses and gloves.
- Turn on the ventilation unit and ensure proper flow.
- Remove the top cover from the fiber bending unit.
    - Gently lift the cover directly up an inch or so to unseat the top. Make sure to keep the top as level as possible so the condensation does not drip all over.
    - With the top unseated, tilt the cover away from you by elevating the end furthest from you and reseat the end closest to you to allow the condensation on the cover to run back into the unit.
    - This will direct the steam/moisture towards the ventilation suction.
- Once the top has sufficiently drained off the condensation, place the cover behind the unit.
- Insert the bundle/plate setup into the bending unit.
    - One technician should handle the base-plate end, while the other technician will handle the chimney-plate end.
    - The three plates should sit flat on the bending unit floor.
    - Be certain not to drop the plates, as this may crack the bending unit.
    - Make sure that the stabilizing cylinder, attached to the bottom threaded rod, is firmly seated on the bending unit floor. This will

position the plates with a slight forward tilt towards the stabilizing stand and prevent the unit from falling over.

- Replace the cover to the bending unit.
    - Ensure it is firmly seated in place.
- Begin the LabView program for "Fiber Bend - Preheat".
    - This will raise the water temperature to 140ºF.
    - 140ºF will be maintained as the water is circulated to heat and remove internal stresses of the fibers.
    - Additionally, the elevated temperature will help to cure the epoxy to full strength faster.
    - Preheating the fibers minimizes the chances of crazing and helps to reduce internal stresses in the fibers.
- Once the program has finished remove the plates from the heat treating unit and place on the bundling table.
    - Start by donning safety glasses and gloves.
    - Remove the top cover from the fiber bending unit.
        - Gently lift the cover directly up an inch or so to unseat the top. Make sure to keep the top as level as possible so the condensation does not drip all over.
        - With the top unseated, tilt the cover away from you by elevating the end furthest from you and reseat the end closest to you to allow the condensation on the cover to run back into the unit.
        - This will direct the steam/moisture towards the ventilation suction.
    - Once the top has sufficiently drained off the condensation, place the cover behind the unit.
    - Remove the bundle/plate setup from the bending unit and place on the bundling table.
        - One technician should handle the base-plate end, while the other technician handles the chimney-plate end.
- Remove the 2 braces between the base & chimney-plates.
- Secure the two chimney-plates onto the threaded rods attached to the base-plate.
    - Start by ensuring that a nut is positioned at the lowest marker on each rod.
    - Next add a: large washer – leveling cylinder – large washer to each rod.
        - The leveling cylinder should be positioned so that the angled end is furthest from the nut.
        - The peak of the angled end should be towards the SciFi end of the setup. This will allow the chimney plates to be orientated

so that the fibers make a bend of approximately 116 degrees.
    - Slowly rotate the chimney-plate labeled "A" onto the 4 rods and seat against the washers.
        - Rotate the leveling cylinder to seat the chimney-plate fully.
    - Now add a: large washer – angled cylinder – large washer to each rod.
    - Slowly rotate the chimney-plate labeled "B" onto the 4 rods and seat against the washers.
        - Rotate the angled cylinder to seat both chimney-plates fully.
    - Add a: large washer – leveling cylinder – large washer to each rod.
        - The leveling cylinder should be positioned so that the angled end is closest to the chimney-plate.
    - Add a nut to each rod and secure the setup firmly in place.
        - The cylinders may need to be rotated slightly to seat the setup completely.
- With the plates firmly in place remove the bending unit as previously instructed and re-submerge the plates into the tank.
- Replace the cover to the bending unit.
    - Ensure it is firmly seated in place.
- Begin the LabView program for "Fiber Bend – Final Heat".
    - This will raise the water temperature to 180ºF.
    - 180ºF will be maintained for 30 minutes.
    - The heater is then secured and the circulating pump will stay on.
- Once the program has finished heating the cover is removed.
    - This will allow the tank to slowly cool towards room temperature.
- The unit is allowed to cool for at least 6 to 8 hours or until the unit is within 20 degrees of room temperature.
    - This step should be performed in the evening so that after the cover is removed the lights may be extinguished in the room to allow the fibers to cool in darkness.
- Once the unit has cooled, secure the circulating pump.
- Ensure the work table in the clean room is clean.
- Place the plate/fiber unit in the drying box in the clean room.
- Cover the drying box with a dark cloth.
- Ensure that the exhaust port for the dehumidifier is properly aligned to blow into the drying box.
- Start the dehumidifier and the timer.
- After 2 hours of drying, remove the bundle from the drying box.
- Check for moisture between the fibers.
    - If moisture is present, reinsert in the drying box for 1 additional hour.
    - After 1 hour, recheck for moisture.
        - If moisture is still present, use a dry lint-free cloth to gently dry the moisture between the fiber layers.

        - Then reinsert in the drying box for 1 additional hour.
- Once the bundle is deemed moisture free, place the plate/fiber unit onto the bundling table to begin the process of removing the fiber bundle.
- Remove the clamps of the 4 guide-chimneys on plate "B".
    - DO NOT remove the clamp on the chimney (the end one). This chimney will remain attached to the fiber bundle throughout the rest of its useful lifetime.
- Remove the 4 nuts, 8 washers, and 4 leveling cylinders from the threaded rods.
    - This will allow the technician the ability to be able to freely remove the first chimney-plate.
- Separate the two chimney-plates slightly and remove the chimney from the first plate.
- Have a second technician hold the chimney out of the way through the next few steps.
    - Make certain that the general shape of the bent fibers is maintained and no unnecessary forces are applied to the fibers.
- Remove the associated chimney-plate from the rods and set aside.
- Remove the clamps of the 4 guide-chimneys on plate "A".
    - DO NOT remove the clamp on the chimney (the end one). This chimney will remain attached to the fiber bundle throughout the rest of its useful lifetime.
- Remove the 8 washers and 4 angled cylinders from the threaded rods.
    - This will allow the technician the ability to be able to freely remove the second chimney-plate.
- Remove the chimney from the second plate.
- Have the second technician hold both chimneys out of the way through the next few steps.
    - Make certain that the general shapes of the fiber bends are maintained and no unnecessary forces are applied to the fibers.
- Remove the chimney-plate and set aside with the other.
- Remove the top halves of all the light guide collars.
- Carefully remove the bundle and place directly into the dark box in the clean room for testing.
    - Reference the "Bundle Testing" procedure for instructions, if needed.

16. Bundle Testing

16.1 Overview

At this point in the construction, each fiber bundle must be tested for light transmission efficiency and crosstalk. The following tests will help to determine deficient bundles.

16.2 Procedures

- Don a clean pair of powder-free gloves.
- Begin by filling out the basic information on the next spreadsheet in the sequence (i.e. bundle number, etc.).
    - It is important to maintain proper "book-keeping" here, so that we are able to correctly reference back to this information after construction has completed.

NOTE: Every testing session begins with a reference fiber.

** First begin using the reference bundle. **

- Open the front panel of the dark box.
    - Start by removing the Velcro attached to the front panel and attaching it to the base of the dark box using the small Velcro strips attached on the backside of the cloth.
        - The light seal for the edges of the front panel consist of the Velcro strips attached to a thick cloth with one mating to the front panel and the other to the base of the dark box.
    - Once the top and side Velcro pieces have been removed from the front panel simply grasp the two panel handles and put to unseat the panel at the top.
        - The front panel is hinged at the bottom and therefore the bottom Velcro strip need not be removed.
    - Rotate the front panel 180 degrees about its hinges and allow it to hang while working inside.
- Open the side panel of the dark box.
    - Start by removing the Velcro attached to the side panel and attaching it to the base of the dark box using the small Velcro strips attached on the backside of the cloth.
    - Once the top and side Velcro pieces have been removed from the side panel simply grasp the panel handle and put to unseat the panel at the top.
        - The side panel is hinged at the bottom and therefore the bottom Velcro strip need not be removed.
    - Rotate the side panel 180 degrees about its hinges and allow it to hang while working inside.
- With the side panel open, use the string attached to the back wall to tie back the center dark cloth.
- Next insert the bundle from the front.
    - Start by feeding the SciFi end of the bundle through the front of the

box and into the side panel.
        - Pay particular attention not to mar the ends of the fibers.
    - Ensure that popsicle stick seats firmly into the allotted holes and notch in the sloping platform of the side panel.
        - Note: a firm seating of the popsicle stick will ensure proper alignment of the fiber ends during testing.
    - Place the two straps over the straight section of the bundle in the side panel to make sure the bundle does not come out of place.
    - Remove the string from the dark cloth and drape the cloth over the bundle.
- With the bundle glued section inserted, attach the chimneys to the back-plate.
    - Start by verify that the fiber-ends are secure and flush to their respective chimney faces.
    - Feed the fibers around the dowel separators.
        - These dowels simulate the small gaps in the shielding portion of the full scale tagger.
    - Carefully insert one chimney at a time into position and attach to the back-plate with screws.
- Make certain that all parts are attached securely.
- From the back of the dark box, install the electronic backplane board.
- Insert the pre-amplifier boards into place.
- Attach the chimney supports to their chimney & stanchion pair.
- Check for loose fibers and misaligned components.
    - Fix any problems and inform the lead technician so they may track any trends and deal with them accordingly.
- Close the front panel of the dark box.
    - Grasp the two handles and rotate the panel into the vertical position.
    - As you rotate the panel, inspect the foam weather stripping along the perimeter of the front panel for damage. Replace sections if necessary since this helps to provide a light tight seal during testing.
    - The front panel has several cabinet door catches which help hold it securely in place. Each catch requires between 3 to 6 pounds of force to close, so firmly grasp the back of the dark box as you seat the front panel into its closed position.
    - With the front panel firmly seated in place, attach the previously removed Velcro back onto the front panel.
        - Ensure that there is a smooth and continuous seal.
- Secure the light source in place.
- Close the side panel of the dark box.
    - Grasp the panel handle and rotate the panel into the vertical position.
    - As you rotate the panel, inspect the foam weather stripping along the

perimeter of the side panel for damage. Replace sections if necessary since this helps to provide a light tight seal during testing.
    - The side panel has two cabinet door catches which help hold it securely in place. Each catch requires between 3 to 6 pounds of force to close, so firmly grasp the opposite side of the dark box as you seat the side panel into its closed position.
    - With the side panel firmly seated in place, attach the previously removed Velcro back onto the panel.
        - Ensure that there is a smooth and continuous seal.
- Commence the LabView program for light transmission test.
- Record the data on the spreadsheet.
- Remove the bundle by reversing the previous steps.
- Use a rubber-band label that indicates the bundle number and the words "QA Pass" on it to place around a passing bundle.
- Place a failed bundle on the side and inform the lead technician for instructions on further actions and possible retesting.
- For failed bundles the setup will be visually inspected in an attempt to determine why they failed.
    - If no explanation for failure is found or an attempt is made to fix the problem, then it will be retested using the aforementioned steps.
    - If the bundle fails once again then place it on the side and inform the lead technician for instructions on further actions and possible retesting.
- Once testing is complete and all bundles have either passed or been discarded, the test data recorded on the spreadsheet will be recorded electronically using Excel and stored on the UConn PAN webpage.
- Pack the passing bundles into their shipping boxes.
- Seal the shipping box and, once electronically recorded, place the associated testing spreadsheets into the see through folder on the outside of the box.
    - Ensure that the bundle number is clearly visible through the folder without having to remove the documentation.
- Store on the shelf in PB-405.

17. Enclosure Assembly

17.1 Overview

The design of the TM includes the use of an upper (fiber) and lower (electronics) enclosure. The construction of these two enclosures will occur in parallel with the fiber bundle construction and testing. The construction of the enclosures for the TM will be based on the finalized drawings made by UConn (to be made). The construction of these components will be manufactured in the UConn physics machine shop, with the GlueX collaborator's at UConn specifying the materials and

drawings that will be used.

17.2 Procedures

- Prior to submitting the drawings for construction, the construction manager will check for:
  - Correct dimensions
  - Proper materials listed
  - Proper tolerances listed
- Once the two enclosures have been fabricated, a wooden mounting structure will be constructed to simulate the mounting structure to be used in the Tagger Hall.
- The two enclosures will be mounted and all fiber bundles and electronics will be installed.
- Cosmic ray testing will be performed to test the fully constructed tagger microscope.
- Any problems with assembly of the full microscope or testing will be reported to the lead technician, electronically logged, and reported to JLab.
  - Consultation with JLab will be sought to remedy possible problems.

II. MICROSCOPE PREAMPLIFIER

0. Introduction

The University of Connecticut (UConn) has developed prototype electronics for the GlueX experiment's tagger microscope. Through designing and testing these circuit boards a construction plan has been developed to outline the production process for the experiment.

1. Redesign

1.1 Preamplifier overview

The current preamplifier board needs to be modified to adhere to the final specifications of the tagger microscope chamber. The circuitry has been tested and proven to function properly but the physical dimensions of the board need to be altered. This will also entail adjustments to the locations of the sub-circuits from each other, for example an individual channel and summing circuit may not be the same distance from each other. Due to the change from 25 micron to 50 micron SiPMs a small addition to the amplifier circuit has been tested and will be included in the final design (see section Additional Electronics Information).

1.2 Electronics redesign plan

During the fall and winter the electronics boards will be redesigned using Altium Designer. Dr. Jones, Alex Barnes and James McIntyre will discuss the board size specifications and will make adjustments to component placements on each board.

2. Order components

2.1 Overview

Changes have been made to the board that require new components and different amounts of previously used components. Most of them can be purchased through Digikey but depending on stock and price another vendor might be used.

2.2 Ordering components plan

Once the redesign has been completed our component inventory will be compared to components needed to populate the board as well as any requirement set by the board manufacturer. A vendor for the parts will be found based on product availability and price.

3. Order the boards

3.1 Ordering plan for the boards

After redesigning the boards and ordering new components we will send our parts and Altium files to a board manufacturer that will create the physical board as well as populate it with the components we specify. The SiPMs and the Eurocard connectors will be soldered by us to guarantee proper alignment. We will order three boards initially to make sure the boards operate correctly before purchasing the whole order.

4. Visual exam

4.1 Examination plan

Once the boards and SiPMs have been received we will perform a visual exam to make sure all of the board components are properly attached and there are no obvious issues with the board and SiPMs. This includes tombstoned components, missing components and solder bridges on the board and scratches on the SiPMs. A microscope will be used during the examination. The visual exam will not entail measuring each component value.

4.2 Examination procedure

- Each preamplifier board must be numbered for identification purposes.
- Using the microscope visually scan each individual channel and summing

circuit as well as the voltage reference and temperature circuit and look for partially soldered components, missing components, and solder bridges.
    - A partially soldered component will have one end attached and will most likely be sticking upright rather than lying flat.
    - Use the provided Smart PDF of the preamplifier to verify that all components are on the board.
    - A solder bridge occurs when solder has formed a connection between components and/or pads that are not to be joined.
- Record in the provided Excel inspection spreadsheet whether the board: passes or component # in X circuit needs to be soldered/resoldered.
- Under the microscope examine each SiPM and look for any scratches or deformities.
    - If there appears to be a scratch clean the SiPM with rubbing alcohol and a Q-tip. Dry the SiPM with compressed air.
    - Examine the SiPM again. If the scratch/deformity is still there measure the resistance across the pads underneath the SiPM. Compare this value to at least three other SiPMs.
        - If the resistance is equivalent to the other SiPMs note the damage in the SiPM specification and placement spreadsheet with a description indicating that the SiPM can still function.
        - If the resistance does not match the other SiPMs record the result in the SiPM specification and placement spreadsheet with a description indicating the SiPM may be defective and requires further testing.

5. Soldering

5.1 Soldering plan

After the boards have been examined any components that were either tombstoned or missing will be soldered and solder bridges will be removed. Once these components have been attached the Eurocard connectors and SiPMs can be soldered onto the boards. To guarantee alignment the Eurocards and SiPMs will be soldered by UConn. These parts can be soldered in the lab at UConn but we will be looking into using the soldering machine at Indiana University as well for soldering the SiPMs. This will speed up the soldering process and reduce the time to a complete set of electronics boards.

5.2 Component soldering

- For any board that failed the visual exam refer to the Excel inspection spreadsheet for the location of missing and tombstoned components and solder bridges.
- Tombstoned components:

    - Remove tombstoned component using a soldering iron.
    - Use the iron and solder wick to remove any remaining solder on the component and pad.
    - For small components:
        - Take a syringe and stick the end into the container of solder paste. Be sure to keep the amount of solder paste on the tip of the syringe to a minimum.
        - Place a small amount of solder onto one of the pads and slide the component into the solder.
        - Hold the component with tweezers and solder the component to the board.
        - Place a small amount of solder onto the other pad and attach it to the component.
- Missing components:
    - Use the iron and solder wick to remove any remnant solder from the pads.
    - Retrieve the missing component from the electronics cabinet.
    - For small components follow the guidelines outlined in the 'Tombstoned components' section above.
- Solder bridges:
    - Remove the bridges using the iron and solder wick.

5.3 Eurocard soldering

- Once the board has been visually examined and no components need to be resoldered the Eurocard can be connected.
- Insert the male Eurocard connector into the preamplifier so that the Eurocard is on the same side as the components.
- Tighten the screw to set the alignment. These screws have been chosen such that when they are tightened the alignment will be within the specifications.
- Solder the pins on the underside using a soldering iron set to a temperature of 650°F.

5.4 SiPM soldering

- Once the Eurocard is soldered the SiPMs can be attached.
- Place the preamplifier in the custom-made holder underneath the microscope.
- Use the vernier caliper to align the notch with the silkscreen outline on the board. This notch is used to hold the SiPM in place while soldering. The silkscreen outlines have been placed to match the locations of the scintillating fibers.
- Place the SiPM in the notch and verify the alignment by using the microscope. The edges of the silkscreen outline will be visible and flush against the SiPM.

- Once the alignment has been verified remove the SiPM with tweezers without moving the calipers.
- Take a syringe and stick the end into the container of solder paste. Be sure to keep the amount of solder paste on the tip of the syringe to a minimum.
- Dab solder on the pads of the preamplifier where the corners of the SiPM will sit. The mounds should be small to prevent spreading to other contacts. These mounds should be placed such that half of them will be under the SiPM and the other half will be exposed to heat.
- Set the hot air gun to 300°C
- Using tweezers place the SiPM into the notch of the calipers. Hold the SiPM in place using a toothpick or other small, non-metal tool. Apply pressure directed towards the notch to keep it in place.
- Use the hot air gun on the right side of the SiPM where the edge is exposed. Do not touch the surface of the SiPM with the toothpick or hot air gun. The solder will have formed a connection when it appears to melt and becomes sucked underneath the SiPM. This will take a few minutes.
- Once the right side is attached slide the caliper and notch away and solder the left side. Wait for the solder to melt and become sucked underneath the SiPM before removing the hot air.
- Record the board number and the SiPM number provided by Hamamatsu in the SiPM specification and placement spreadsheet.
    - This document will be created once the SiPMs have been received.
- If a SiPM becomes damaged during the soldering process record this in the SiPM specification and placement spreadsheet. Return the damaged SiPM to its original package.

III. BIAS CONTROL BOARD

1. Redesign

1.1 Control board overview

The current control board needs to be modified to adhere to the final specifications of the tagger microscope. The circuitry has been altered and tested and now must be included in the drawing. Depending on the changes on the backplane, the control board may need to be resized or have the traces from the Eurocard adjusted.

1.2 Electronics redesign plan

During the fall and winter the electronics boards will be redesigned using Altium Designer. Dr. Jones, Alex Barnes and James McIntyre will discuss the board size specifications and will make adjustments to component placements and values on

each board.

2. Order components

2.1 Ordering components plan

Once the redesign has been completed our inventory for the control board components will be compared to components needed for the design. Components will be purchased from a vendor based on product availability and price.

3. Order the boards

3.1 Ordering plan for the boards

After redesigning the boards and ordering new components we will send our parts and Altium files to a board manufacturer that will create the physical board as well as populate it with the components we specify. We will order three boards initially to make sure the boards operate correctly before purchasing the whole order.

4. Visual exam

4.1 Examination plan

Once the boards have been received we will perform a visual exam to make sure all of the board components are properly attached and there are no obvious issues. This includes tombstoned components, missing components and solder bridges on the board. A microscope will be used during the examination. The visual exam will not require measuring each component value.

4.2 Examination procedure

- Each control board must be numbered for identification purposes.
- Using the microscope visually scan the board and look for partially soldered components, missing components, and solder bridges.
    - A partially soldered component will have one end attached and will most likely be sticking upright rather than lying flat.
    - Use the provided Smart PDF of the control board to verify that all components are on the board.
    - A solder bridge occurs when solder has formed a connection between components and/or pads that are not to be joined.
- Record in the provided Excel inspection spreadsheet whether the board: passes or component # in X circuit needs to be soldered/resoldered.

IV. MICROSCOPE READOUT BACKPLANE

1. Redesign

1.1 Backplane Overview

The current backplane board needs to be modified to adhere to the final specifications of the tagger microscope chamber. Adjustments to the grounding plane as well as the location of some components has changed and must be updated in the drawings. Part of the redesign will entail resizing the board to match the requirements of the new microscope chamber.

1.2 Electronics redesign plan

During the fall and winter the electronics boards will be redesigned using Altium Designer. Dr. Jones, Alex Barnes and James McIntyre will discuss the board size specifications and will make adjustments to component placements on each board.

2. Order components

2.1 Ordering components plan

Once the redesign has been completed our inventory will be compared to components needed and a vendor will be found based on product availability and price.

3. Order the boards

3.1 Ordering plan for the boards

After redesigning the boards and order new components we will send our parts and Altium files to a board manufacturer that will create the physical board as well as populate it with the components we specify. We will order three boards initially to make sure the boards operate correctly before purchasing the whole order.

4. Visual exam

4.1 Examination plan

Once the boards have been received from the manufacturer we will perform a visual exam to make sure all the components are properly attached. We have a microscope to help view the small components.

5. Solder the lemo connectors

5.1 Attaching the lemo connectors

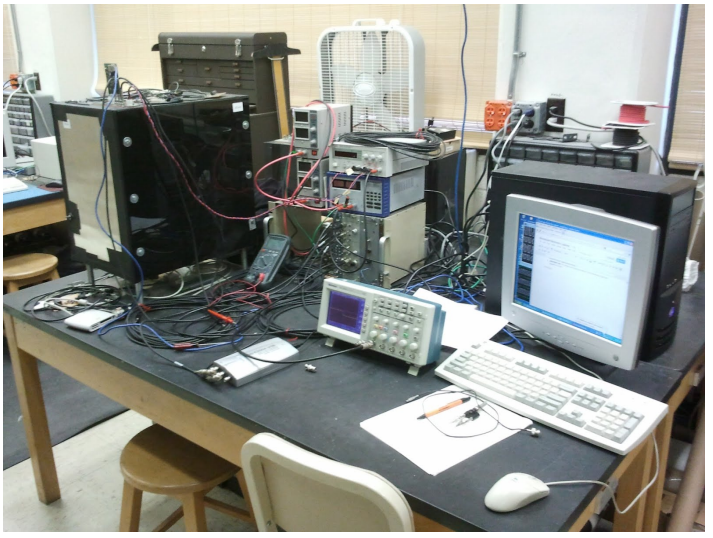
After examining the board the lemo connectors are to be attached.

- Place the lemo on the board so that the pins go through the board
- Solder the pins so the wells fill with solder.

V. ADDITIONAL ELECTRONICS INFORMATION

1. Workstation images

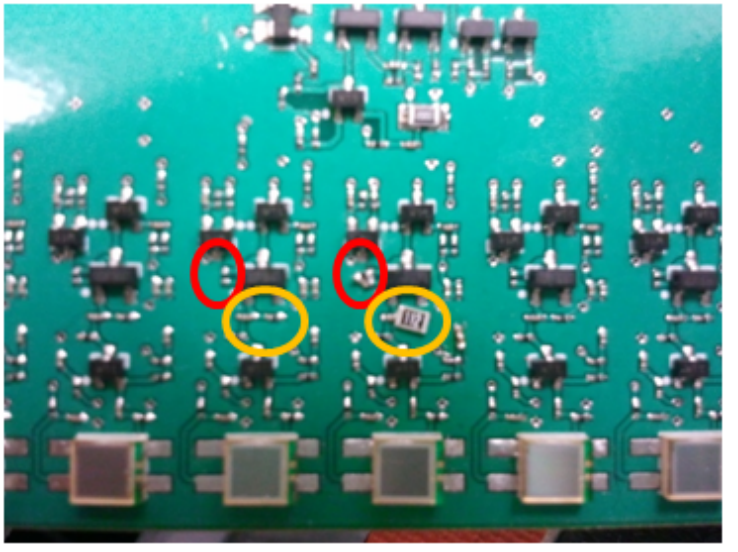
FADC workstation



Electronics testing station including the first microscope

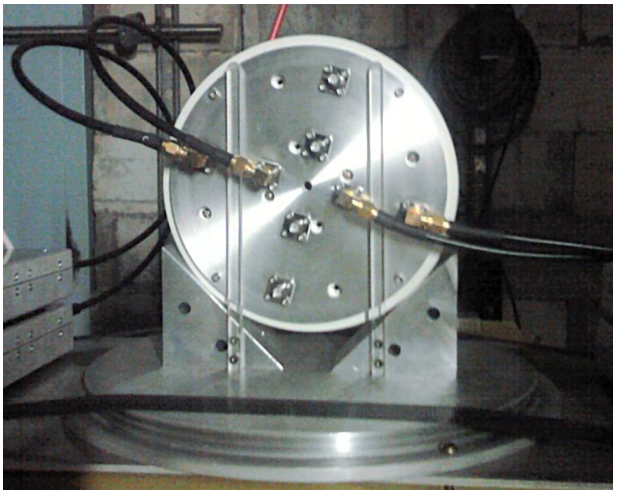
testing chamber, power supplies, NIM bin and modules, PC oscilloscope, and testing computer.

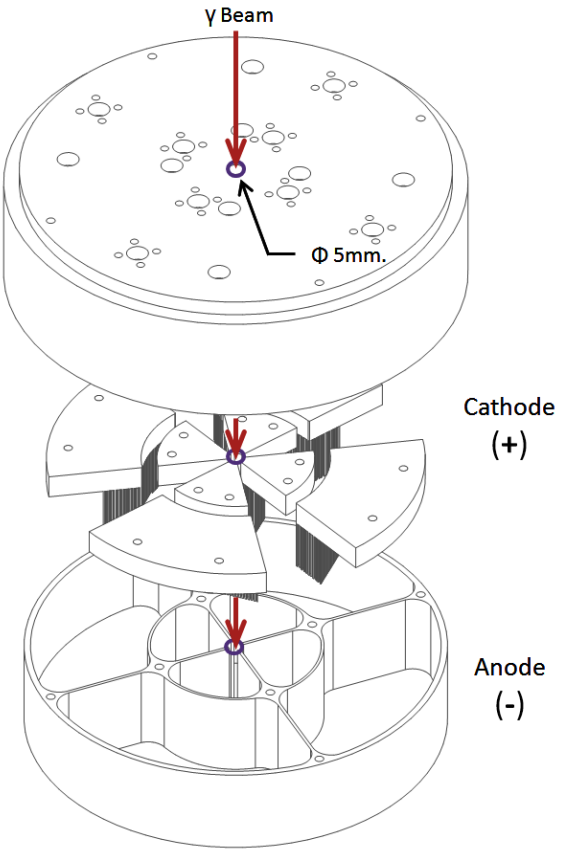
Soldering station including a microscope, soldering iron and supplies, hot air, and electronics board holder.



Changes made to the preamplifier due to the 50 μm SiPM. The left side is the 25 μm and the right circuit is the 50 μm. The red circle indicates an added parallel RC circuit and the yellow circle corresponds to adjustments to specific resistors.

VI. ACTIVE COLLIMATOR





1. Wedge Cleaning

1.1 Overview

The eight pincushion wedges installed in the active collimator are fabricated by Electrostatic Discharge Machining (EDM) at Florida State University. Once shipped to UConn these wedges require delicate cleaning prior to installation. An assembly workstation, in the cleanroom at UConn, has been dedicated for the construction of the active collimator. The cleaning of all construction materials will take place outside the cleanroom and then the materials will be immediately transferred to the cleanroom for storage and subsequent assembly. The following procedures detail the initial cleaning steps taken outside the cleanroom.

1.2 Procedures

- Don safety equipment:
  - eye-protection
- Make certain the cleaning station table is clear of debris and clean.

- Don a clean pair of powder-free gloves.
- Remove the wedges from their shipping packages and set aside:
    - Make sure to gently unwrap each wedge, taking special care not to catch any pins of the wedge on the packing material as it is unwrapped.
    - Place the wedges in the center of the far left side of the table. This allows ample space for cleaning and helps to minimize accidental damages.
- Taking one wedge at a time and clean as follows:
    - Grasp the wedge firmly in one hand with the pins facing away from the palm.
    - Use a compressed air bottle to blow away any foreign debris.
        - Make certain to get between the pins.
        - Keep the tip of the air nozzle at least 1 to 2 inches from the pins.
    - Using a lint-free cloth dampened with ethyl alcohol, gently wipe the flat surfaces of the wedge.
        - Note: **DO NOT** allow the cloth to come in contact with any portion of the pins.
    - Again, use compressed air as detailed previously to blow away any foreign debris.
        - Note: Keep the tip of the air nozzle at least 1 to 2 inches from the pins.
- Visually inspect the clean wedge, looking for:
    - Damage to the pins
    - Unclean sections
    - Defects in the wedge
- Take a photographic log of all defects or damages.
- Report damages and defects to the lead technician.
- Store the cleaned wedge in the designated area on the assembly station in the cleanroom.
- Repeat the previous steps for cleaning until all unpackaged wedges are cleaned.
- Log the work session in the online logbook, detailing:
    - Quantity cleaned
    - Effectiveness of cleaning
    - Damages or defects
    - Photographic documentation

2. Insulator Cleaning

2.1 Overview

The eight pincushion wedges will sit inside an insulated housing. Prior to assembly

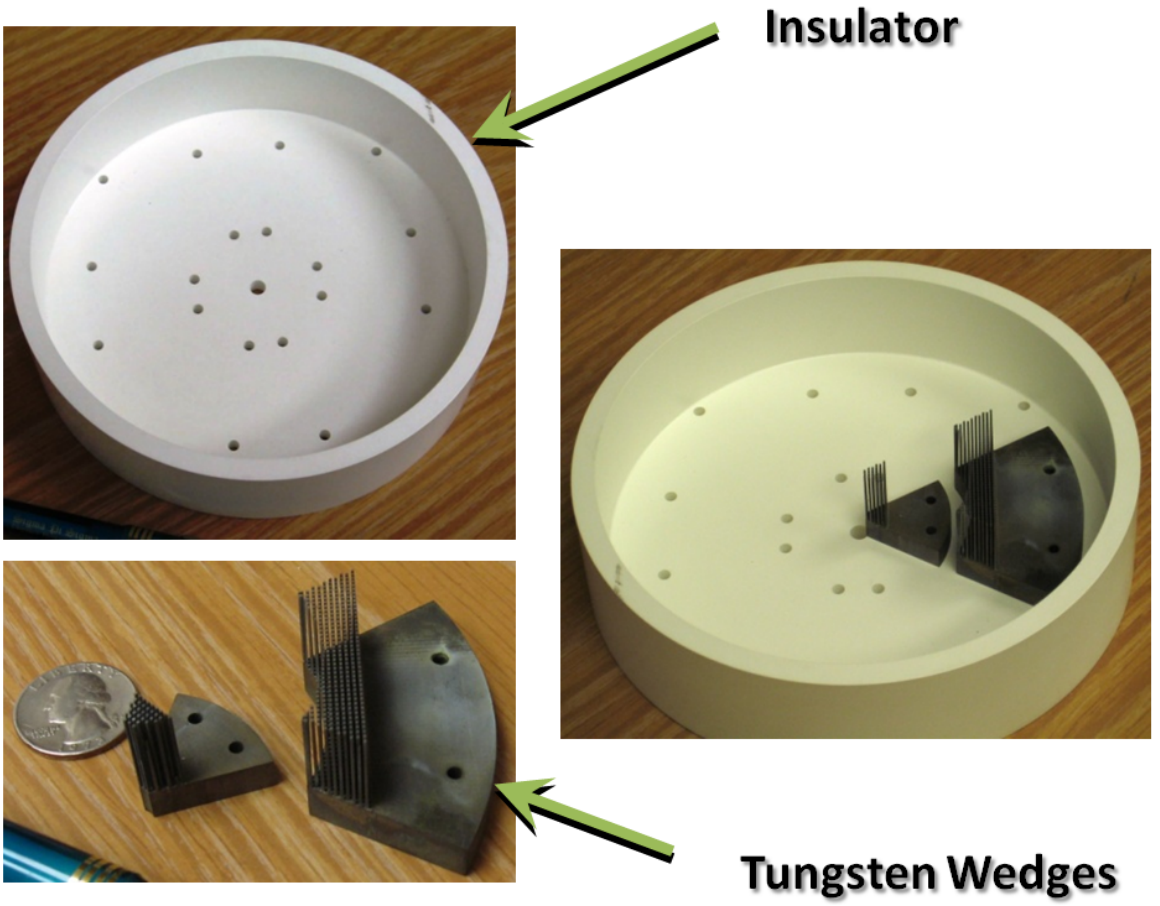
of the components of the active collimator inside the housing, a thorough cleaning of the components must take place. The cleaning of all construction materials will take place outside the cleanroom and then the materials will be immediately transferred to the cleanroom for storage and subsequent assembly. The following procedures detail the initial cleaning steps taken outside the cleanroom for the housing structure of the active collimator.

2.2 Procedures

- Don safety equipment:
  - eye-protection
- Make certain the cleaning station table is clear of debris and clean.
- Don a clean pair of powder-free gloves.
- Remove the components from their storage packaging and set aside:
  - Make sure to gently unwrap each component, taking special care not to catch any pins of the wedge on the packing material as it is unwrapped.
  - Note: Several wedges have already been installed during the prototyping phase.
- Take one component at a time and clean as follows:
  - Grasp the component firmly in one hand with the pins facing away from the palm (if applicable).
  - Use a compressed air bottle to blow away any foreign debris.
    - Make certain to get between all the mating surfaces of the components.
    - Keep the tip of the air nozzle at least 1 to 2 inches from the pins, when applicable.
  - Using a lint-free cloth dampened with ethyl alcohol, gently wipe the flat surfaces of the different components.
    - Note: **DO NOT** allow the cloth to come in contact with any portion of the pins.
  - Again, use compressed air as detailed previously to blow away any foreign debris.
    - Note: Keep the tip of the air nozzle at least 1 to 2 inches from the pins.
- Visually inspect the component, looking for:
  - Damage & defects
  - Unclean sections
- Take a photographic log of all defects or damages.
- Report any defects or damages to the lead technician.
- Store the cleaned components in the designated area on the assembly station in the cleanroom.
- Repeat the previous steps for cleaning until all parts of the active collimator

assembly are cleaned.

- Log the work session in the online logbook, detailing:
    - Materials cleaned
    - Effectiveness of cleaning
    - Damages or defects
    - Photographic documentation



3. Assembly

3.1 Overview

There eight pincushion wedges (4 inner and 4 outer tungsten wedges) to be installed in the active collimator. An assembly workstation, in the cleanroom at UConn, has been dedicated for the construction of the active collimator. The following procedures detail the assembly of the AC inside the cleanroom at UConn.

3.2 Procedures

- Make certain the assembly workstation is clean and clear of clutter.

- Don a clean pair of powder-free gloves.
- Center the insulator bowl in front of the technician in the middle of the table.
- Place all other components neatly off to the side for future use.
- Install the inner tungsten wedges:
    - Begin by placing one inner wedge (smaller sized wedge) onto the insulator bowl.
    - Align the wedge so that the through holes on the flat section of the wedge mate with their associated holes (inner ring of holes) on the bowl.
        - A general visual alignment is all that is needed at this stage.
    - Thread two bolts through the holes in the wedges and securely fasten to the insulator using nuts and washers.
        - Start by passing the bolts through the holes until they come in contact with the assembly station table.
        - Next slowly lift the bowl while applying slight pressure to the top of the bolts.
        - If the bolts do not seat fully on the wedge with the bowl elevated off the table, then realign the wedge and try again.
        - With the bolts seated on the flat surface of the wedge, attach a washer and nut to secure the assembly in place.
    - Repeat the previous steps until all 4 inner wedges are securely assembled.
        - <u>Note</u>: While assembling the subsequent wedges, pay close attention to the location of the pins on the already installed wedges to ensure they are not damaged during assembly.
- Install the outer tungsten wedges:
    - Follow the previous steps used to install the inner wedges for installation of the outer wedges (larger sized wedges)
    - <u>Note</u>: While assembling the subsequent wedges, pay close attention to the location of the pins on the already installed wedges to ensure they are not damaged during assembly.
- After all wedges have been installed, perform a visual inspection to look for:
    - Damage and defects
    - Unclean sections
    - Foreign debris
- Clean as necessary using the previously stated procedures.
- Take a photographic log of all defects or damages.
- Report damages and defects to the lead technician.
- Assemble the outer housing:
    - Attach the top cover
    - Thread though the bolts and attach with a nut and washer

- Visual inspect, looking for:

    - Damage
    - Loose fittings
    - Foreign debris
- Take a photographic log of all damages.
- Report damages to the lead technician.
- Log the work session in the online logbook, detailing:
    - Quantity cleaned
    - Effectiveness of cleaning
    - Damages or defects
    - Photographic documentation

4. Testing

4.1 Overview

After assembly of all the components for the AC, a thorough round of bench tests must be performed. The following procedures detail the bench testing that will be conducted at UConn.

4.2 Procedures

- Make certain the testing workstation is clean and clear of clutter.
- Don a clean pair of powder-free gloves.
- Attach the cables to the AC front panel.
- Perform testing outlined in QA Plan document
- Log the work session in the online logbook, detailing:
    - Testing data
    - Non-conformities