Construction and Testing of the Photon Tagger Microscope for the GlueX Experiment

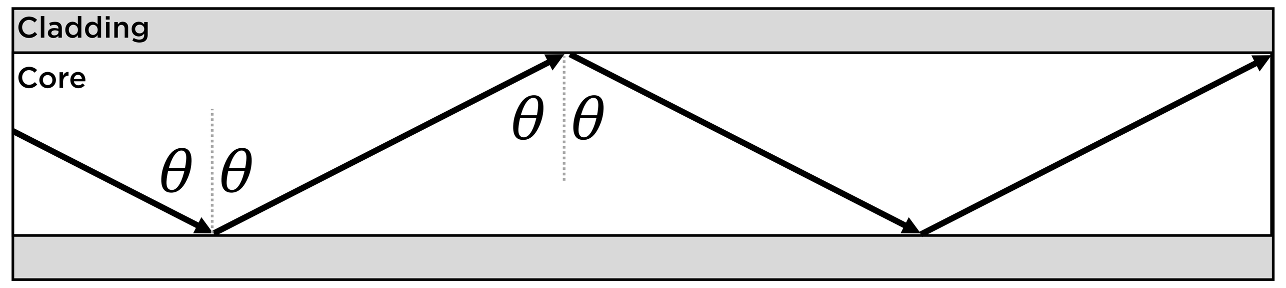
Liana Hotte

James McIntyre, Ann Marie Carroll, Alex Barnes, Brendan Pratt, Richard Jones

Abstract

The GlueX experiment at Jefferson Laboratory (JLab) in Newport News, VA is conducting a search for a new type of particle called an exotic meson. Exotic mesons are predicted to exist by the Standard Model of Particle Physics. Experiments searching for exotic mesons have reported evidence for their existence over the past 25 years, and recently the LHC at CERN has produced the first definitive confirmation of their existence. GlueX is designed to produce them in large numbers so that their mass spectra can be determined and other properties studied. To do this, GlueX requires a beam of high-energy polarized photons, generated by passing high-energy electrons from the JLab accelerator through a diamond crystal, whose energies are then "tagged" by measuring how much energy the electrons lost in the crystal. This function is provided by the tagger microscope, a highly-segmented scintillation detector which detects the degraded electrons and measures their energy and time. As electrons strike a scintillating fiber, an optical signal is transmitted to a silicon photomultiplier which converts it to an electrical signal to be digitized and recorded. The University of Connecticut successfully completed the construction and testing of the tagger microscope in 2014 and delivered it to JLab, where it is now operating as part of the GlueX experiment in its first year running.

Optical Fibers



Basics of Optical Fibers

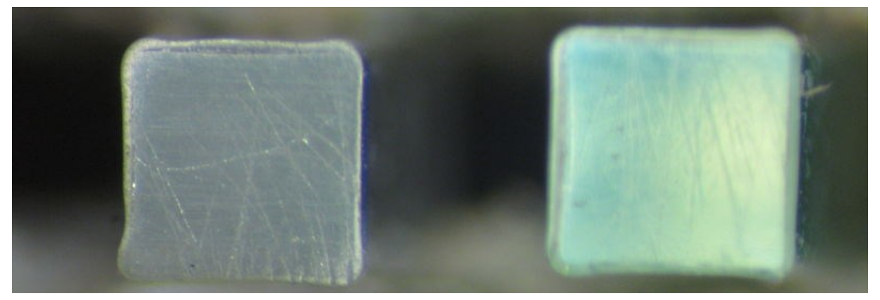
Optical fibers transmit light signals through a process called **total internal reflection** in which the optical signal reflects within the fiber core from one end of the fiber to the other with minimal loss. Total internal reflection is possible because $n_{core} > n_{cladding}$.

Saint Gobain Inc. Optical Fibers

- Polystyrene core (n=1.60)
- PMMA acrylic cladding (n=1.49)
- Fluoracrylic 2nd cladding (n=1.42)

2mm x 2mm square fibers

BCF 98 Clear Lightguide | **BCF 20 Green Scintillating**

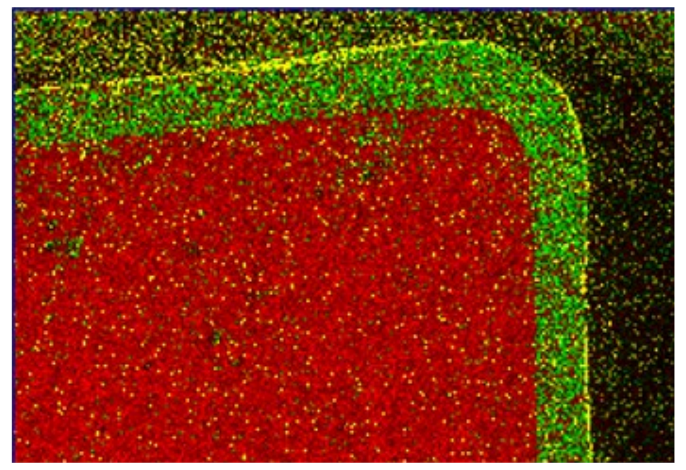


Energy Dispersive X-Ray Spectroscopy

Carbon - red

Oxygen - green

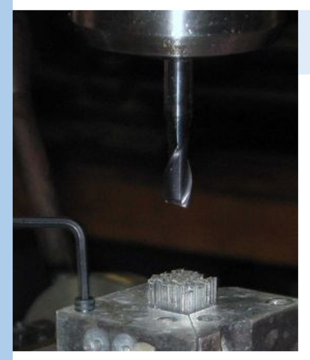
Fluorine - yellow



Fiber Production for GlueX

The tagger microscope is a highly segmented electron detector which "tags" the photons from the GlueX experiment. In order to get the resolution required, **17 bundles of 30 fibers per bundle** are required. Each fiber can resolve approximately 5 MeV, allowing the tagger microscope to detect electrons initially in the 3.0-3.6 GeV range.

Cutting

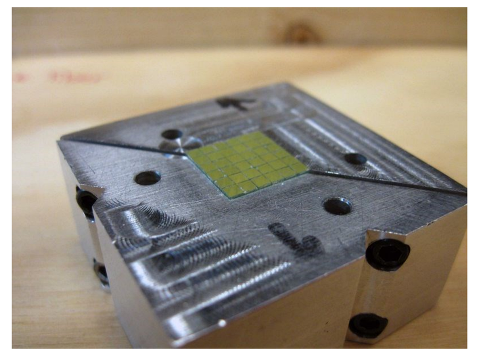


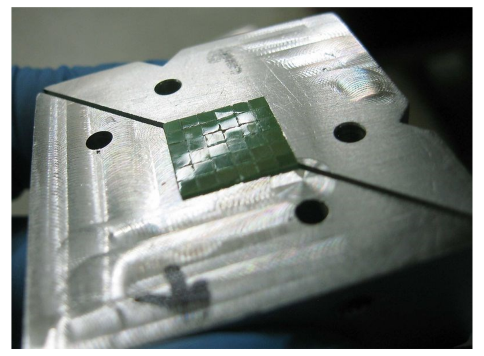
Fibers were rough cut with a rotary power tool and then end milled with a milling machine for a clean cut finish.

Rough Cut	Fine Cut/End Mill
BCF 20 - 2.2-2.4 cm length	**BCF 20** - 2.0 ± 0.1 cm length
BCF 98 - 167.3-5 cm length	**BCF 98** - 166.6 ± 0.5 cm length

Polishing

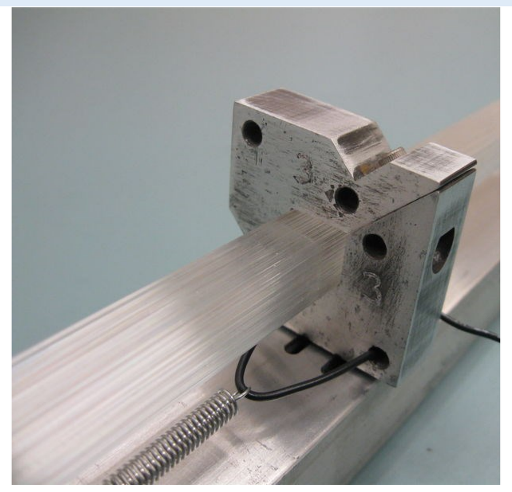
Fiber ends were polished to a mirror finish to optimize light transmission. Fiber ends were polished with 800 grit sandpaper, then 2000 grit, and finally standard copy paper.



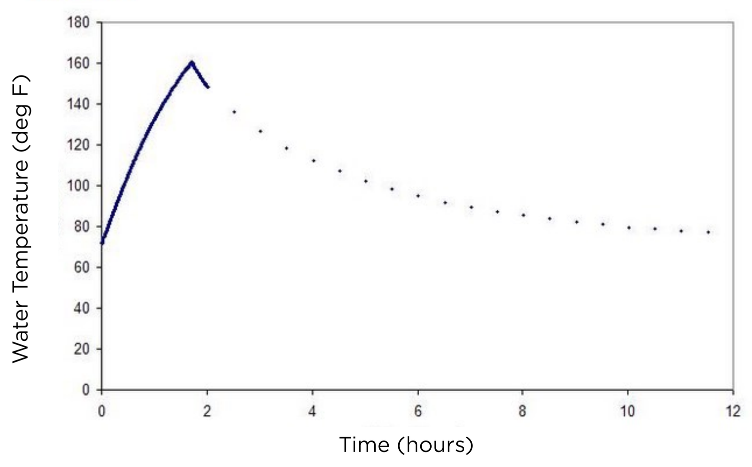


Straightening

The optical fiber was delivered from Saint Gobain Inc. on large cylindrical spools, resulting in a slight bend in the fibers after being cut and so the long, clear light guide fibers had to be straightened for easier handling. The light guides were attached to a large aluminum straightening rod and secured with fiber collars. A small tension was applied to the collars to pull the fibers straight while being heated to 160°F in a water tank.

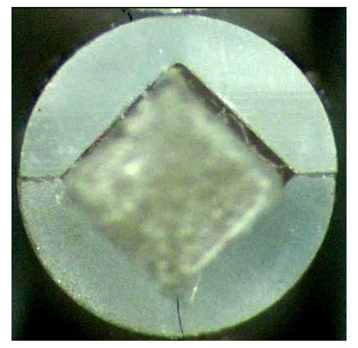


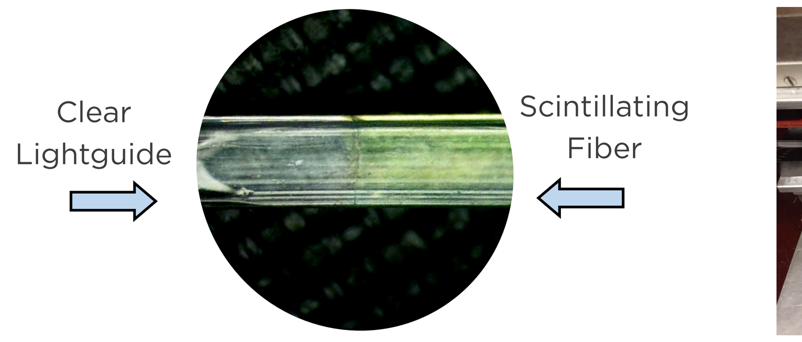
Heating Schedule for Straightening Fibers in Water

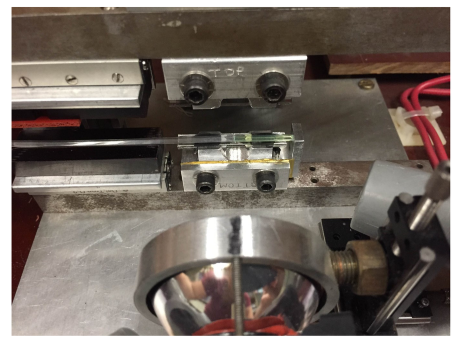


Fusing

A fusing unit from Michigan State University was modified to fuse our square fibers. New glass ferrules were installed which held the fibers in place and kept their size and shape during the fusing process. The polished and straightened fibers were placed in the ferrules and heated with a lamp as pneumatic-controlled clamps pushed the fibers together to fuse their cores.

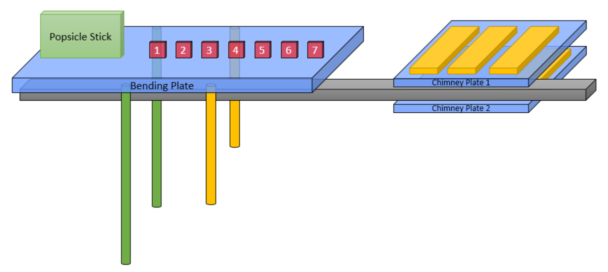


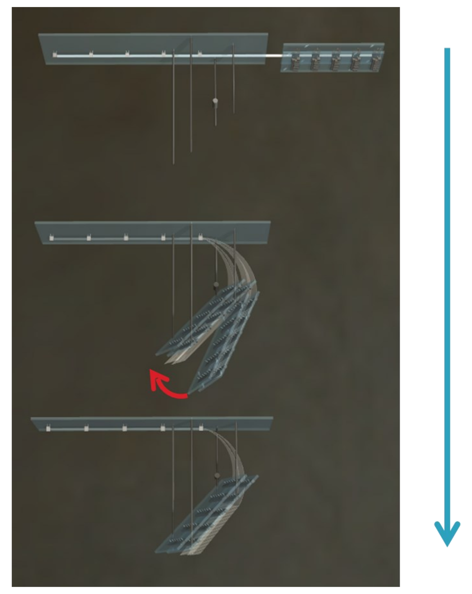




Bending

Bundles of fused fibers were bent using the same process used for straightening. Fibers were heated in a hot water tank and then bent into the shape required for the detector. An S-bend was introduced to the fibers after the fuse joint to remove the lightguide from the plane of the incoming electrons.





Testing and Installation

A pulsating red light was used to test the fibers in Storrs, CT before shipment and installation to JLab. A testing darkbox was constructed to measure the photon yield transmitted by the fibers to the silicon photomultipliers (SiPMs) which digitize the signal.

In September 2014, the 21 bundles (17 required, plus spares) of scintillating fibers were shipped to Newport News, VA and installed into Hall D at Jefferson Laboratory. The tagger microscope is currently operating as a part of the GlueX experiment.

References

1. GlueX Experiment (www.gluex.org)
2. Construction of the Tagger Microscope (www.zeus.phys.uconn.edu/wiki/index.php/Construction_of_the_Full-scale_Tagger_Microscope)

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