LGT Alignment Project Report, 4-26-2010

Using Fiber Optics as Light Sources for a BCAM

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Overview

Our design uses the LWDAQ to control modified A2051 boards. Each modified A2051 is capable of powering up to four LEDs independently. Each LED is attached to a separate optic fiber which runs along the length of the Long Guide Tube (LGT) from one end and terminates in a mount at a specified point along the tube. The terminal ends of the fiber optics emit a bright point of light. A BCAM is positioned near the end of the LGT opposite the end from which the fibers originate. All terminal ends of the fiber optic along the LGT are simultaneously within view of the BCAM. Each terminal end of the fiber optic can be flashed via the LWDAQ independent of other fiber ends. By flashing each fiber optic at various times throughout the articulation of the LGT, the position of various points can be recorded. It will then be possible to use software and measurements of the distance from fiber ends to the LGT to reconstruct the movement of the LGT and better understand how forces and torques applied to it change its shape.

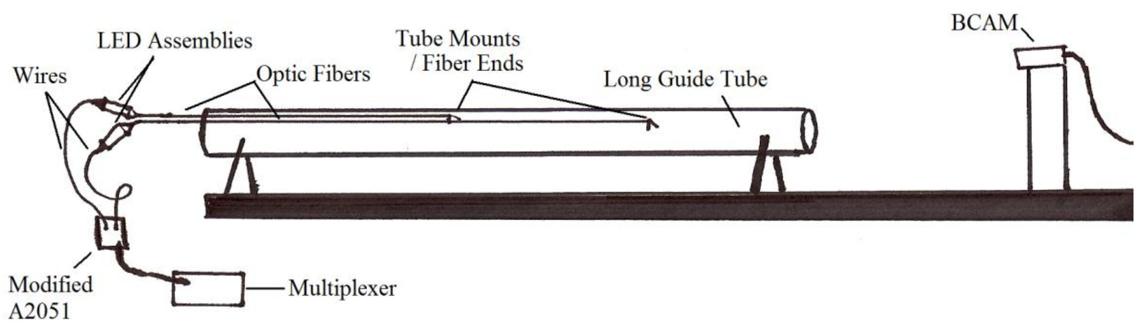

Figure: This figure is not to scale. Note that in actuality, each A2051 can control 4 optic fibers and that several A2051s will be used. The BCAM in the right of the image has a view of the fiber ends along the LGT.

A2051 & LED Connection

The A2051 Polar BCAM Head is capable of independently flashing four laser diodes through the LWDAQ BCAM instrument. In this project, the laser diodes are replaced with LEDs. This means that the light sources connected to an A2051 can be operated just as though they were lasers in an A2051. Therefore, functions such as flash adjust automatically work with the optic fiber system just as they would in normal BCAM operation.

The power source for each laser is attached to a 1.20m twisted pair wire terminated in a molex connector. This connection circumvents the board containing the laser diodes which is not used. Each twisted pair delivers a 15V differential capable of driving an LED.

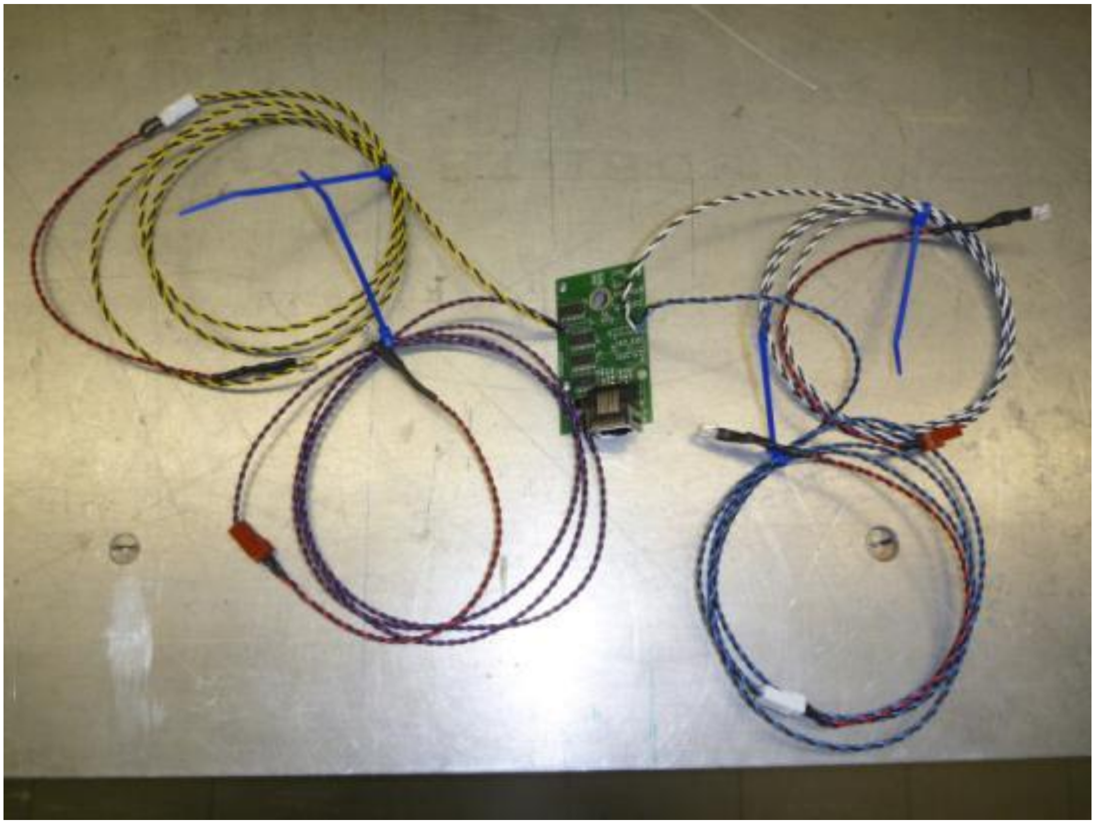

Figure: A modified A2051 board. LED assemblies (red and black wires) are shown attached to each twisted pair.

LED Assemblies

Each LED is attached to a 20cm length of twisted pair wire terminated in a molex connector to allow connection to the modified A2051. FH1011 LEDs manufactured by Stanley Electric are predominantly used in this experiment (see below for more discussion on LEDs). This LED is attached in series with a resistor which delivers the appropriate current for the LED. Connections between the wire, molex connector, resistor, and LED are encased in heat shrink tubing.

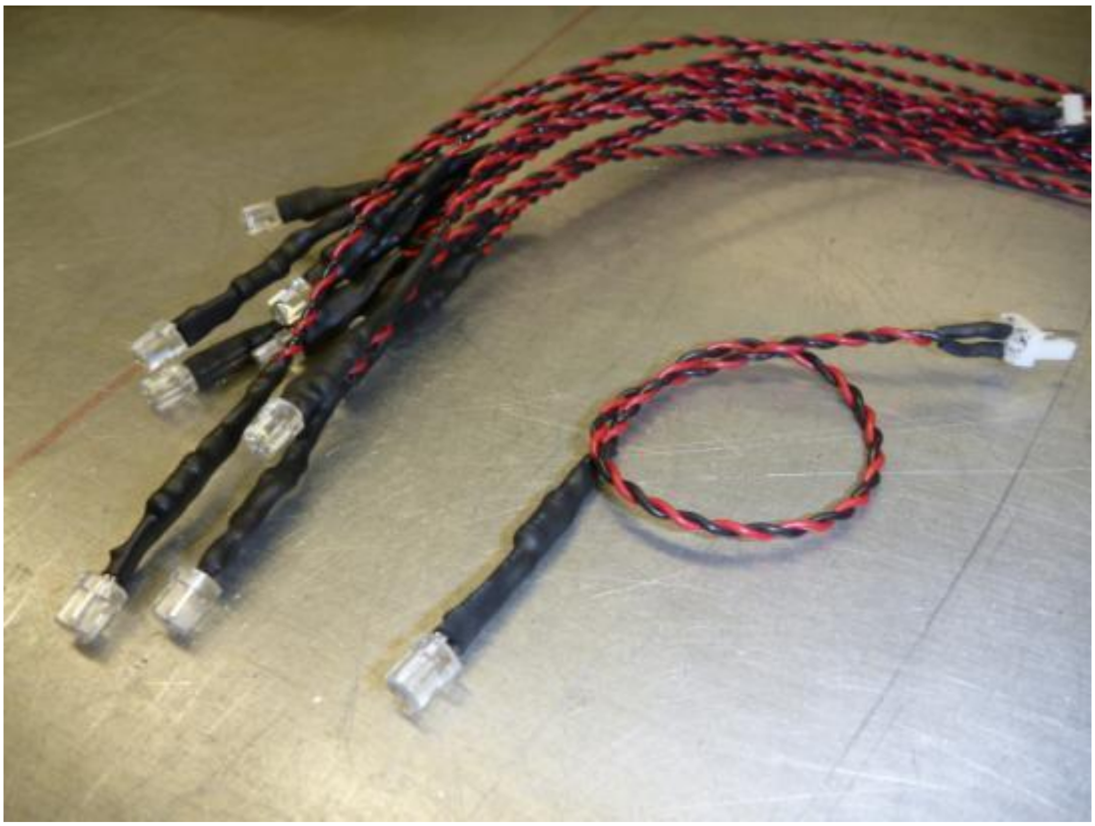

Figure: 20cm, FH1011 LED assemblies.

Optic Fibers

In this experiment, 1000 micron diameter ESKA acrylic polymer fibers manufactured by Mitsubishi are used. They are capable of delivering light the 6m down the length of the Long Guide Tube (LGT). The lengths used in the experiment will range from 1m to 7m. Initial experiments were conducted with jacketed fiber, which is sheathed in a black, protective polyethylene jacket. Unjacketed fiber is identical to the core of jacketed cable and will be used in the preliminary LGT alignment experiment because of the weight savings.

Of crucial importance to the success of the experiment is the polishing of each fiber end. This ensures that the light is stable within the fiber and that an even gradient of brightness across the face of terminal fiber end is attained. The polishing process uses the same lapping film used on the ends of glass optic fibers. Three grits of lapping film are used with the finest being 1 micron film. The film adheres to an aluminum base plate with a drop of water. The end of the fiber is then fed through a hole in a polishing jig. The jig is moved in figure-eight motions over coarse lapping film until the end of the fiber is perfectly flush and orthogonal to the direction of the fiber. The process is then repeated with finer grits of lapping film until an extremely smooth surface is obtained.

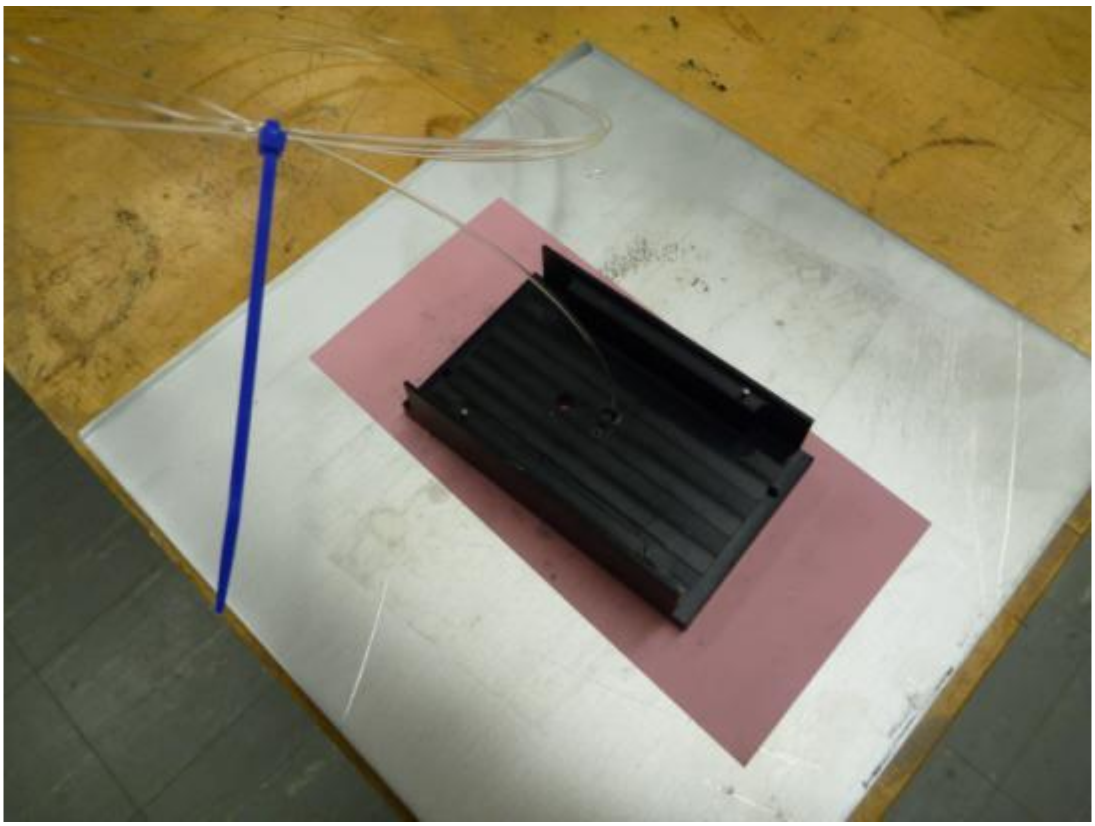

Figure: The end of an optic fiber being polished in a polishing jig on 3 micron lapping film.

LED to Optic Fiber Connection

The optic fibers are connected to LEDs with two-part optical grade epoxy. Both Loctite Hysol E-30CL and 3M DP-105 have been shown to make secure, transparent junctions between the LED and fiber. They both allow light to be efficiently injected from the diode into the fiber. The Hysol E-30CL is better suited for this application due to its greater rigidity. The lab has acquired a one part UV-curing optical grade adhesive called NOA 68T. Initial tests with this adhesive indicate that it is also capable of creating a secure and efficient junction between the fiber and LED. NOA 68T will likely be the adhesive ultimately used for joining fibers to LEDs for use with the LGT due to its ease of application and fast curing speed.

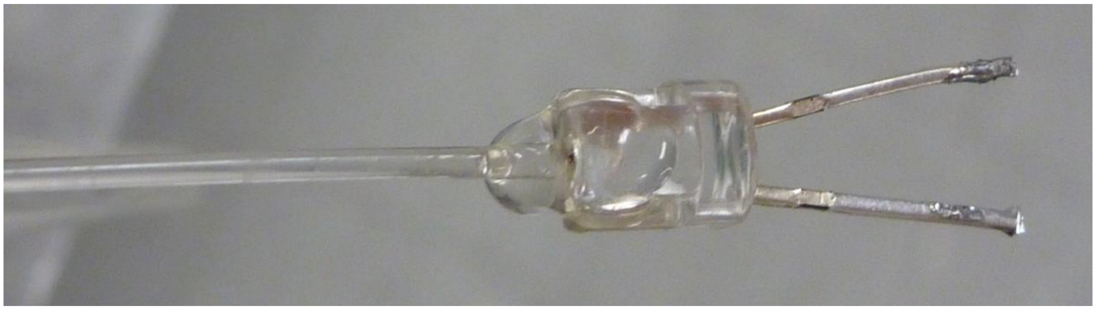

Figure: FH1011 LED secured to one end of an ESKA 1000 micron fiber with two-part optical epoxy.

Tube Mounts

When the ends of fibers are glued directly to the LGT, the light they emit is reflected by the aluminum surface of the LGT and this reflection interferes with the BCAM's recognition of the fiber tip. Therefore, it is necessary to reduce the reflection to a level at which it does not interfere with the image analysis. This is accomplished by raising the fibers a known distance off of the LGT.

The fiber optics will be attached to the LGT using 3/8" long sections of .5"x.5" aluminum angle stock, 1/16" thickness. The two legs of these sections will be epoxied to the LGT. The end of the fiber will then be epoxied into the inside of the corner of the bracket. This raises the fiber approximately 1.5cm above the surface of the LGT. Using this method, the reflection is reduced to an intensity which isn't mistaken for the actual light source in the analysis.

It is possible that some of these mounting brackets will obscure the BCAM's view of others behind them as many are added to the LGT. In this case, some tube mounts will be crafted using an identical technique out of .75"x.75" and/or 1"x1" stock. By raising the light source higher, they will be visible behind the shorter .5"x.5" mounts in front of them.

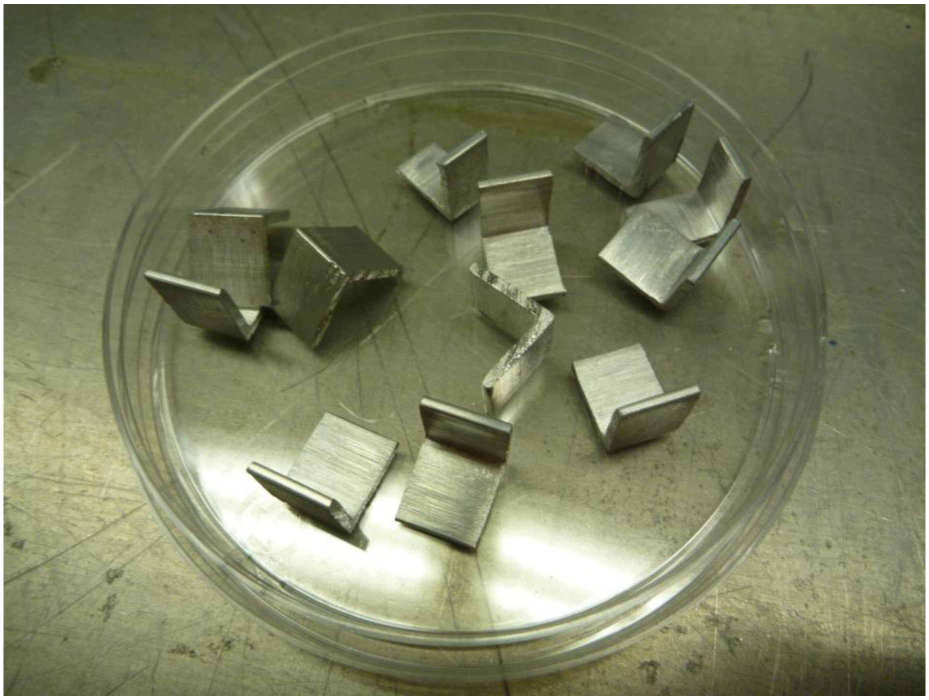

Figure: Sections of .5”x.5”x.0625” angle stock prepared to be mounted to the LGT.

Figure: Two tube mounts resting atop one end of the LGT. The fiber end will be attached to the inside of the apex each forms.

BCAM

A Blue Azimuthal BCAM has been mounted several meters from the end of the LGT in a way such that it has a field of view stretching from one end of the LGT to the other.

Figure: A BCAM mounted for observation of the LGT.

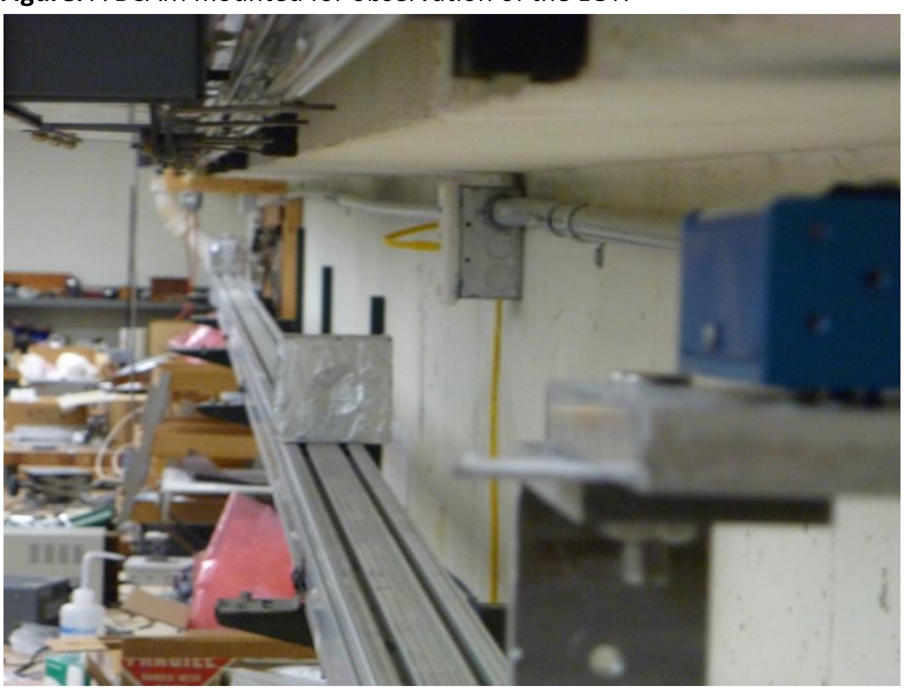

Figure: BCAM’s point of view. The LGT has been temporarily removed. It will rest above the aluminum track starting near the far end of the track and ending just behind the foil-wrapped brick in the foreground.

Light Source Stability

Initial tests have shown the light coming from the ends of the optic fibers to be highly stable. Resolution is expected to be at a level well below 10 microns, safely under the 100 micron precision necessary for the LGT alignment experiment. More experiments are currently being conducted which will hopefully confirm this expected high precision.

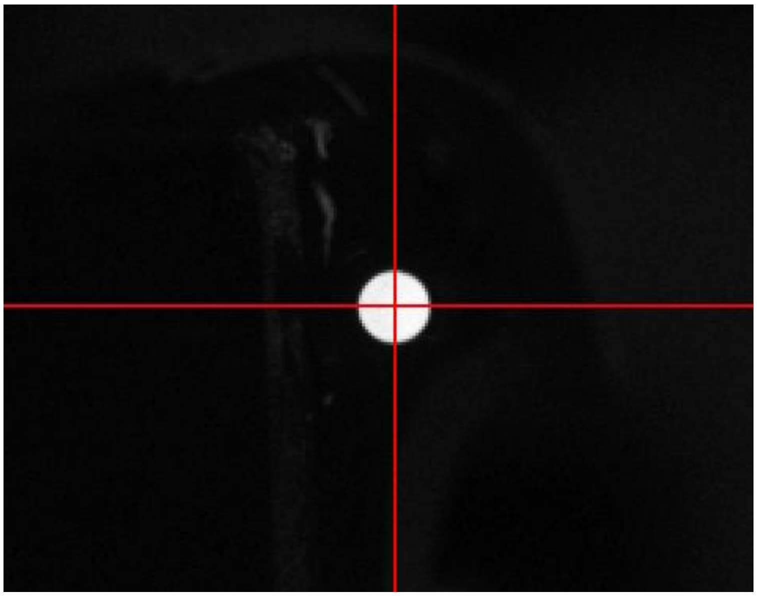

Figure: An image captured of the end of a 1000 micron ESKA fiber being illuminated by an FH1011. Properly polished and free of debris, the fiber tip appears as an evenly illuminated circle.

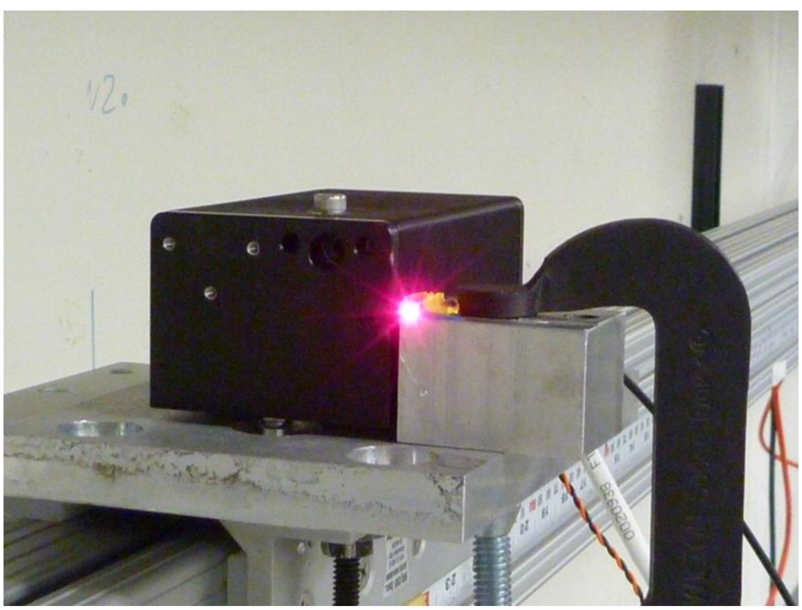

Figure: The tip of the fiber is photographed while flashing. To the human eye, the point of light produced is comparable to that produced by a laser diode.

Other LEDs

The FH1011 has been the most used LED in our experiments, primarily because the lab had a stock of them when we began this work. Four characteristics make it a good diode for light injection into fibers. Most basically, it is a high intensity LED capable of producing enough light to brightly illuminate a fiber end. Unlike many LEDs, its top is flat, which allows fiber ends to be mounted flush with it. The light-emitting chip is positioned very close to the top of the package, increasing the amount of light which enters the fiber, rather than escaping at wide angles into the environment around the LED. It is a rugged LED with a current rating well above most other similar products. For all its merits, the FH1011 is no longer in production. This is not a bad thing, however; in the time since it was developed, LED technology has progressed greatly.

We are now experimenting with newer LEDs which are far brighter than the FH1011 and operate at a similar or lower current. Most notably, TT Electronics' PLCC4 surface mount LEDs, such as the OVSA1GBC2R8 are extremely bright. Like the FH1011, these LEDs have a flat top surface which is very close to the actual light producing chip (less than 1mm). In addition to being brighter than the FH1011, modern LEDs come in a variety of colors (including the FH1011's red). The FH1011 produces light predominantly in the 660nm region, while the newer OVSA1GBC2R8 produces light predominantly in the 527nm region. Colors such as this should allow more efficient transmission through the acrylic ESKA fibers and may exhibit other beneficial qualities as well. Initial experiments with these LEDs are very promising. Some will be incorporated into the LGT alignment project as their utility is proven.

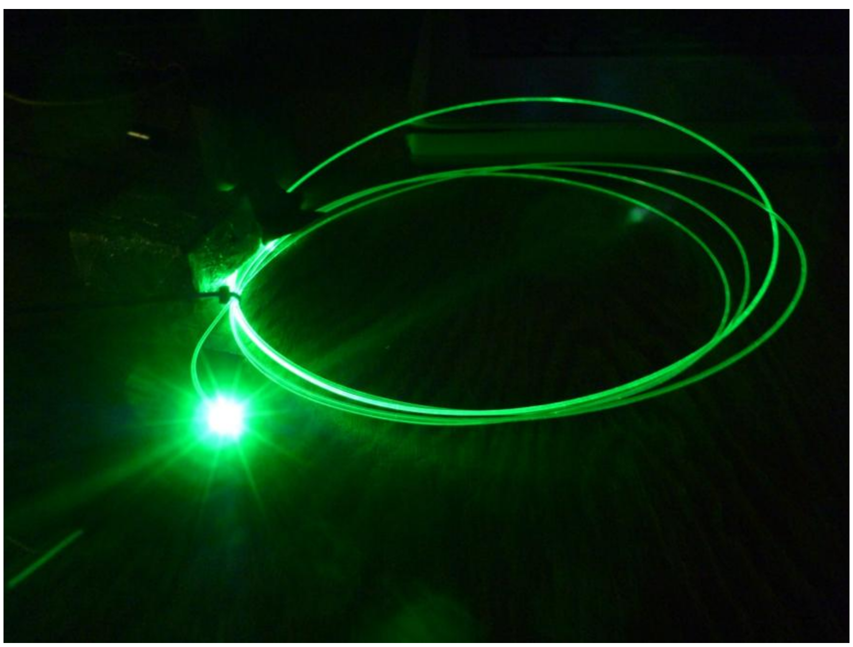

Figure: A 1000micron ESKA fiber being illuminated by an OVSA1GBC2R8. The high-intensity spot in the lower left is the tip of the fiber emitting light.

Conclusion

Currently, there are 5 modified A2051 boards prepared, enough to power 20 light sources. 20 matching LED assemblies have also been prepared. More A2051s and LED assemblies can be easily prepared as necessary. Wires have been created and installed to control the observing BCAM. A wire has also been installed near the opposite end of the LGT and attached to a multiplexer that will control the modified A2051s. Fibers of the various lengths to be used must be cut, polished, and glued to the LEDs. The emitting ends of the fibers will then have to be glued into the tube mounts and those mounts glued to the LGT. This system should then be ready for data collection.

We will meet to determine the critical points at which fiber ends are to be mounted along the LGT. The current plan is for the sources to be attached in pairs at 60cm intervals, 10 pairs, 20 light sources in all. By attaching two fiber tips at each given length - set several centimeters directly across from one another - we will be better able to reconstruct any twisting motions which may arise in the LGT.