CTOF Light Monitoring System Design Considerations

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ctof-lms-design.tex

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Abstract

This document details several of the design considerations for the CTOF Light Monitoring System, including the fiber mounting blocks that attach to the CTOF light guides and the fiber bundle assembly.

1 CTOF Light Monitoring System Overview

The average timing resolution for the CTOF counters along their full length that is required by the design specifications for the system is 60 ps. Given that the CTOF counters are located only 25 cm from the beam-target interaction region, this will be a challenge to achieve and maintain. In order to be able to track the response of each PMT very closely with time, a Light Monitoring System (LMS) will be included as part of the CTOF system. The LMS will pulse light into each PMT at a rate of $\sim$1 Hz. These monitoring events will be part of the CLAS12 trigger configuration and will allow for detailed tracking with respect to time of the PMT gains and the individual counter timing response. These data will allow for more precise offline timing calibrations to be completed for each CTOF counter.

1.1 LMS Components

The components of the CTOF LMS include:

- The light source and driver;
- The integrating sphere;
- The fibers and alignment harness;
- The fiber couplers.

A block diagram of the CTOF LMS is shown schematically in Fig. 1. Each of the different components of the system is described below.

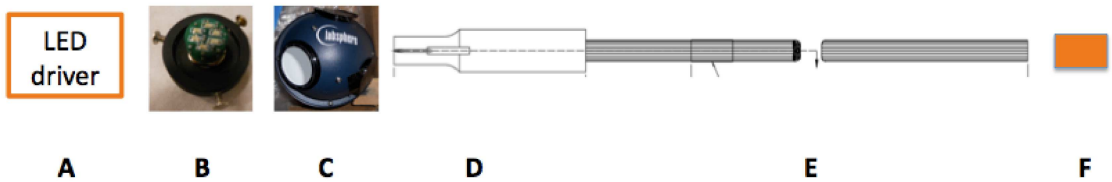

Figure 1: Block diagram of the CTOF Light Monitoring System identifying each of the system components. A. LED driver, B. LED source, C. Integrating Sphere, D. Fiber harness, E. Fiber bundle, F. Fiber coupler to light guide.

1). The *light source* has been designed by the JLab Detector Group. As seen in Fig. 2, the light source consists of 6 LEDs fitted with a focusing lens that contains the light within a desired angular spread. The *driver* associated with the light source is currently being designed at JLab. In bench testing, a prototype light source has been shown to deliver 1×10^7 photons/pulse. If this system directed all photons in each pulse to the fibers coupled to the CTOF PMTs, this would result in 1×10^6 photons at each PMT photocathode. However, the light losses in the coupling from the LED source to the fibers must be considered, as well as the light losses in the fibers, attenuation length effects, and the PMT photocathode quantum efficiency.

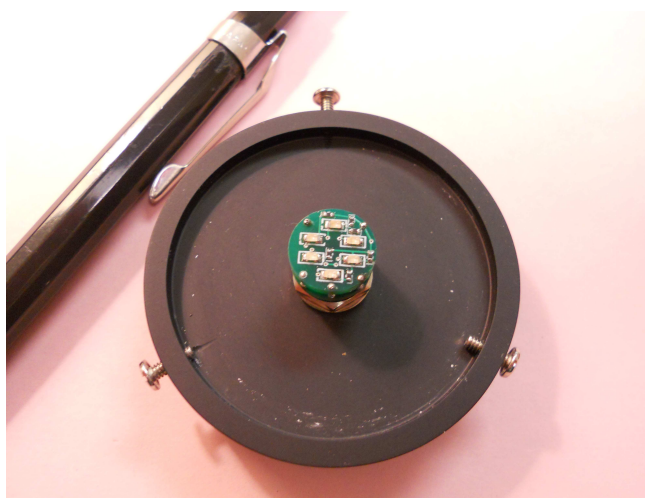

Figure 2: Photograph of the light-emitting diode (LED) light source for the HTCC LMS. The circuit board includes 6 LEDs each fitted with a focusing lens to collimate the produced light. A similar board will be employed for the CTOF LMS.

2). The *integrating sphere* for the CTOF LMS will be a commercial unit. The sphere will contain two ports. The light source will connect to one port and the fiber bundle assembly will connect to the other port. The purpose of the integrating sphere is to ensure that each fiber has the same acceptance for light from the source. The integrating sphere for the HTCC LMS is shown in Fig. 3.

Figure 3: Photograph of an integrating sphere. The LED source in Fig. 2 attaches directly to the open port. The other two ports are used for fiber attachment and for monitoring.

Figure 4: Photograph of the HTCC LMS fiber bundle assembly with each fiber individually jacketed. The fibers are attached to a fiber harness to align the fibers. The fibers are polished at each end.

3). The *fiber bundle assembly* connects the light source/integrating sphere to the counters. It consists of ∼5-m-long glass fibers. The fibers will be bundled together in a harness to connect to the integrating sphere and then free at their other end to run to their mounting locations on the individual counters. Fig. 4 shows the fiber bundle assembly for the HTCC with the fiber harness that attaches to the integrating sphere. Fig. 5 shows the plastic disk port cover that attaches to the fiber harness to allow for coupling to the integrating sphere.

Figure 5: Photograph of the end of the HTCC fiber bundle assembly coupled with the plastic disk that mates the assembly to a port on the integrating sphere.

4). The *fiber mounting blocks* are small plastic fixtures that attach to the light guides of each counter near the PMTs. They have a small channel into which a fiber is inserted and locks into place. The light from the fiber then passes into the light guide through a small hole in the counter wrapping materials.

2 Fiber Mounting Blocks

<u>Details</u>

- One fiber mounting block will be mounted at each end of each CTOF counter near the PMTs at positions as roughly indicated in Fig. 6. The mounting blocks will be made from a black opaque plastic.
- The fiber mounting blocks will have a contour on their inner surface to match that of the light guide for suitable mating (see Fig. 7) and they will contain a small channel into which a brass fiber ferule assembly (attached at the end of each fiber - see Fig. 8) inserts and locks into place such that it can be removed for servicing.
- The fiber should be positioned in the mounting block at an angle such that it points to the center of the PMT photocathode. Note that the fiber will be flush with the ferule at the insertion end.

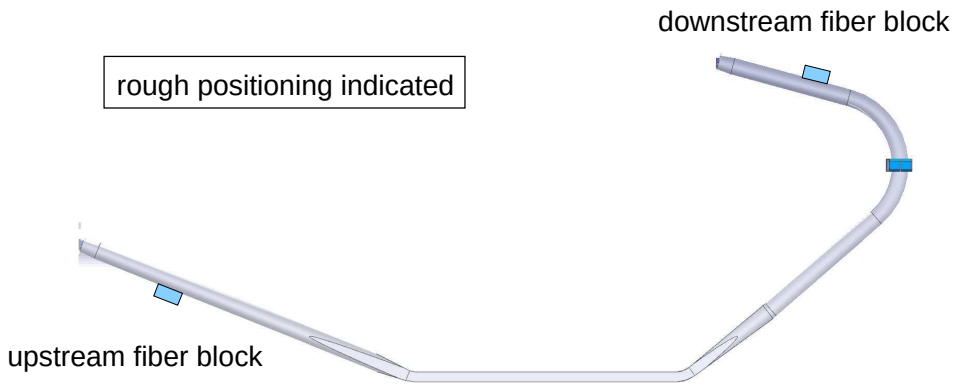

Figure 6: Side view of a CTOF counter showing the rough positioning of the fiber mounting blocks at the ends of the light guides near the PMTs.

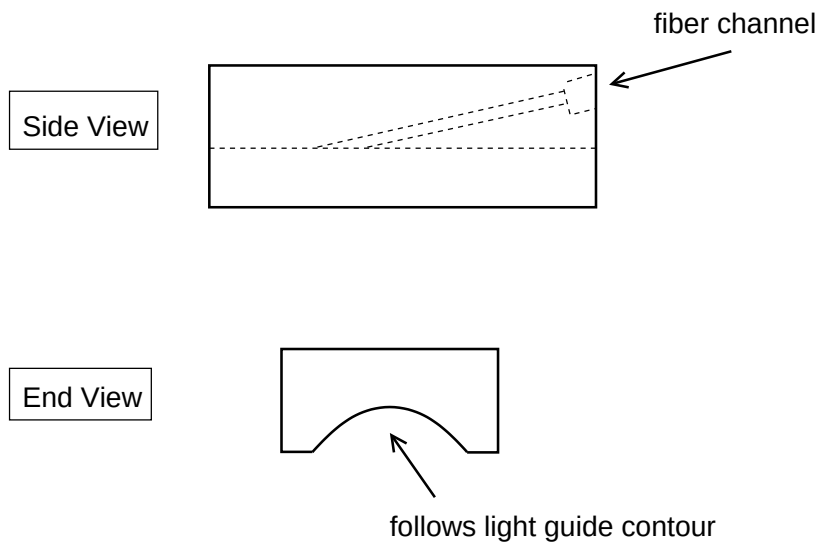

Figure 7: View of a representation of a generic fiber mounting block showing a side and an end view.

Figure 8: Representation of the brass fiber ferule and the jacketed fiber inserted into the fiber mounting blocks.

- The ferule end should contact the light guide but will not be flush to its surface due to its attachment position and angle. The remaining air gap at the light guide surface will be filled with BC-630 optical grease. This grease can be injected via a syringe.
- The opening on the fiber mounting block into which the fiber inserts could have a counterbore slightly larger than the ferule size to ensure there are no sharp edges that can stress the fiber inside its jacket.
- The fiber attachment to the light guide must be designed so that it is light tight.

Fiber mounting block attachment

- Need to position the fiber mounting blocks away from any clamps and structures on the detector support system.
- Need to ensure that there are no conflicts with CND.
- Need to be able to attach the fiber mounting blocks on the light guides in a position that they can be installed on the carts in the CTOF work area.
- Need to cut through the Tedlar, VM2000, and electrical tape wrapping materials without scratching the light guides to make an opening for the light to penetrate. The holes may be slightly over-sized. Perhaps some type of vacuum or suction system can be used to pull the material off the light guide surface and allow a cut to be made.
- Use epoxy to attach the blocks to the light guide surface and to provide a light tight seal.
- Final securing of the fiber mounting blocks can use an overwrap of electrical or Mylar tape.
- Need to be able to access the blocks to service broken fibers.
- The azimuthal positioning of the fiber mounting blocks is arbitrary.

3 Fiber Bundle Assembly

The individual fibers that run from the LED light source to the CTOF counters will be part of a fiber bundle assembly as shown in Fig. 9. The fibers in this assembly will be bundled together at the light source end into a harness that connects to the light source. The individual fibers will then be routed along their respective paths around the solenoid to the individual counters. The nominal plan for this fiber bundle assembly is to include 110 fibers. This allows for extra fibers to replace any that may be broken during installation or work around the detector. The nominal length of the individual fibers in this assembly is 5 m, although this length needs to be confirmed from the model and discussions with Eugene Pasyuk. The design of the fiber bundle assembly is qualitatively very similar to that already designed and procured for the HTCC Light Monitoring System. To date, several

design drawings of the fiber bundle harness have been prepared for the HTCC (see Figs.10 and 11). The design for the CTOF harness will be very much the same. It simply needs to be properly scaled to accommodate the choice of fibers for CTOF.

For the CTOF Light Monitoring System the best match of the overall fiber bundle size to the LED light source is achieved using 600 μm diameter fibers. For this application, clad and jacketed glass fibers will be employed. In early 2015, contact with LEONI Fiber Optics, Inc. from Williamsburg, VA (Mike Pichette, Sales Engineer, mpichette@leoninfo.com) was established. This is the same company that manufactured the HTCC fiber bundle assembly. The relevant details for the fibers provided is:

- 600 μm diameter glass fiber core
- 660 μm diameter glass fiber core + cladding layer
- 710 μm diameter glass fiber core + cladding layer + polyimide coating layer
- The individual fibers are then enclosed in a PVC jacket

The nominal plan would be to provide the fiber optic company with the fiber harness and the ferules. They would then manufacture the fiber bundle assembly according to our specifications. The assembly process would involve removing the PVC jacket from one end of the fibers to attach the ferule (the polyimide coating layer would remain). With the ferule attached, the fiber ends would then be polished. At the other end of the fibers, the PVC jacket would be removed from the last several inches of the fibers. They would then be close-packed and inserted into the harness (again the polyimide coating layer would remain). The ends of the fibers would then be polished. Note that the fibers would enter into the end of the harness with their PVC jackets undisturbed.

The final element of the CTOF fiber bundle assembly that needs to be designed is the attachment of the fiber bundle assembly to the integrating sphere. As shown in Fig. 3, the integrating sphere has a circular port attachment for the fiber bundle assembly. Fig. 5 shows the recommended solution that was, in fact, developed for the HTCC. The fiber harness mounts to a plastic disk compatible with the port on the integrating sphere.

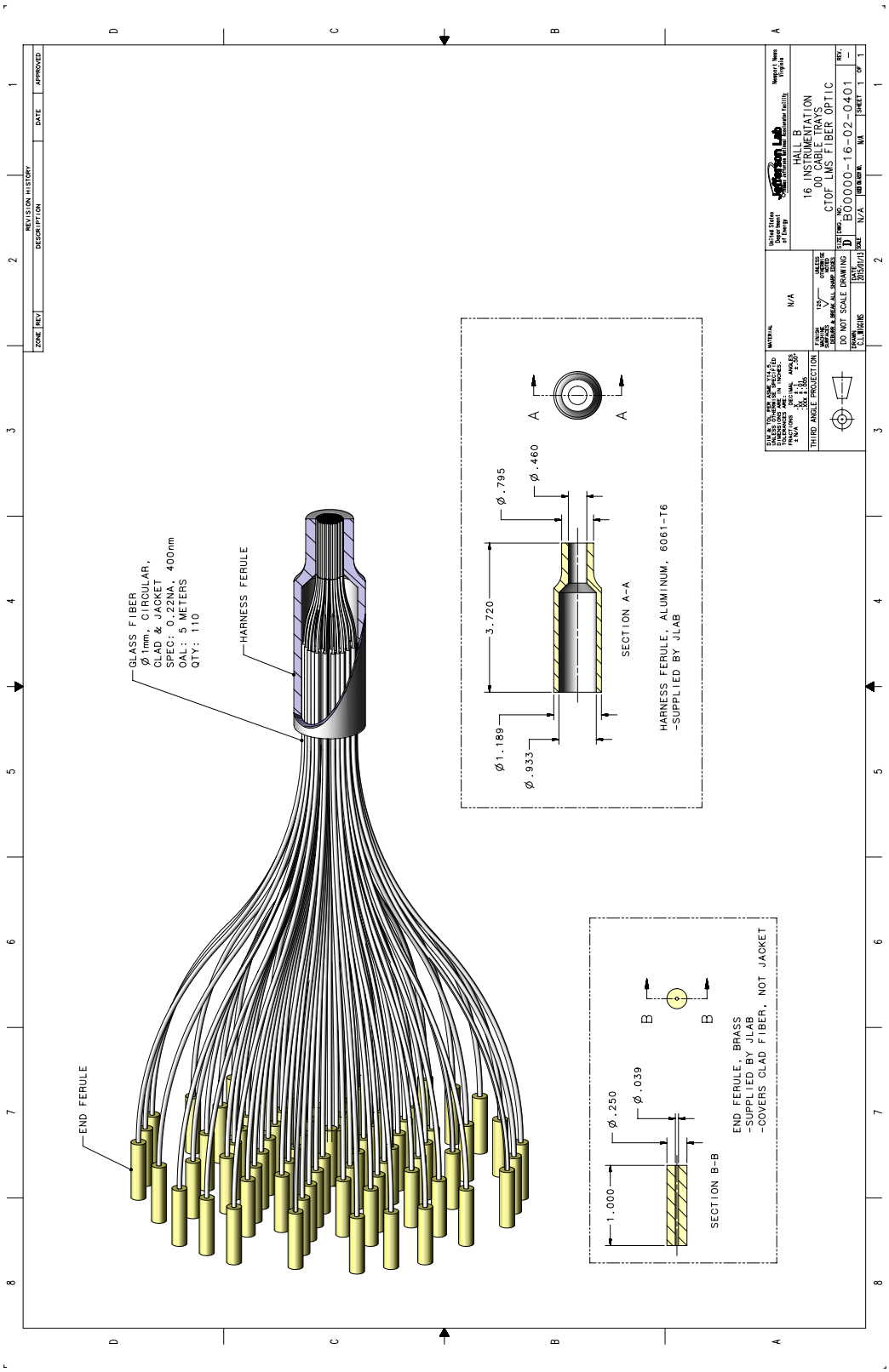

Figure 9: Schematic drawing of the CTOF LMS fiber bundle assembly. Ref. Drawing B00000-16-02-0401.

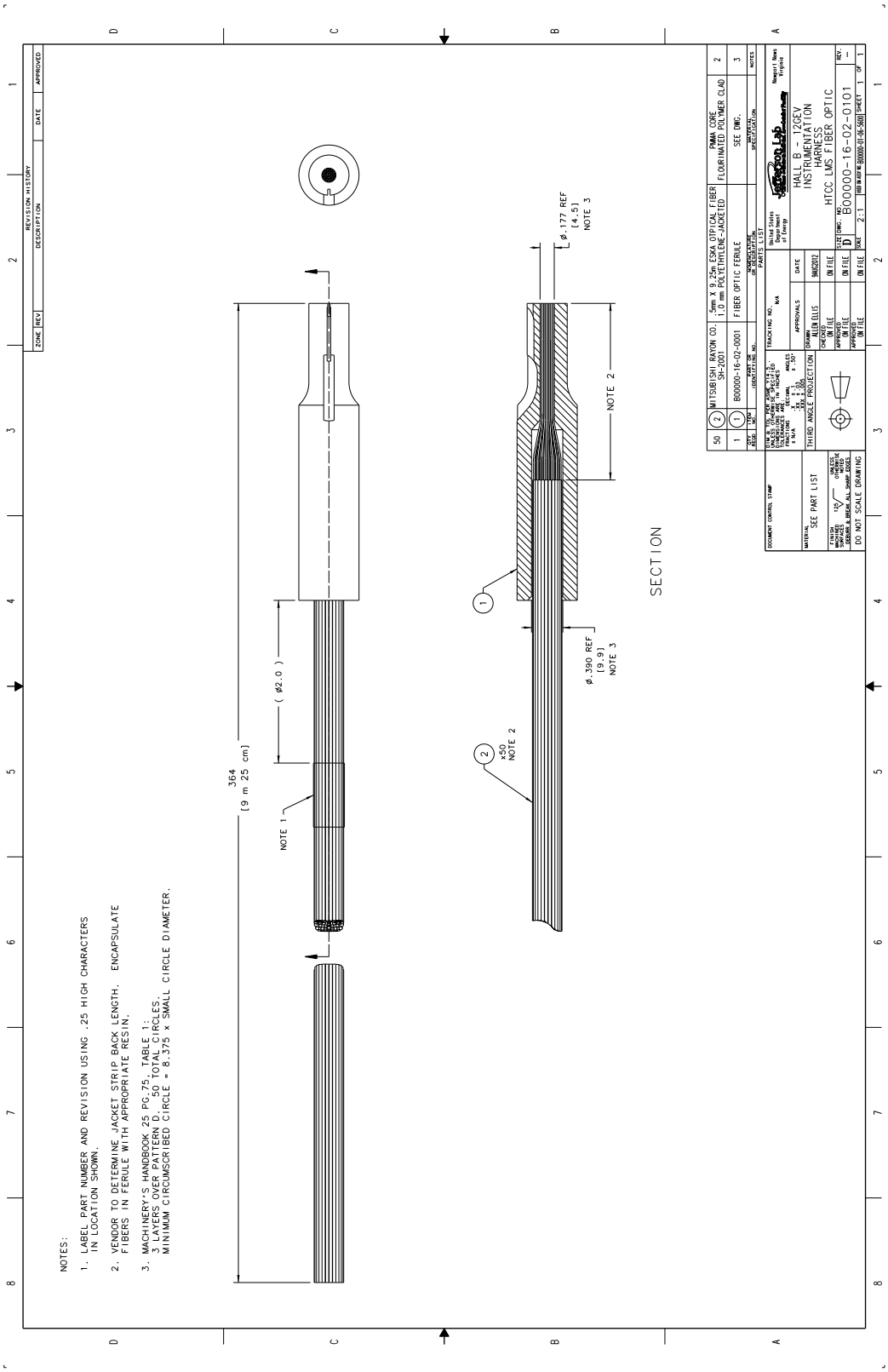

Figure 10: Fiber bundle assembly for the HTCC LMS. Ref. Drawing B00000-16-02-0101.

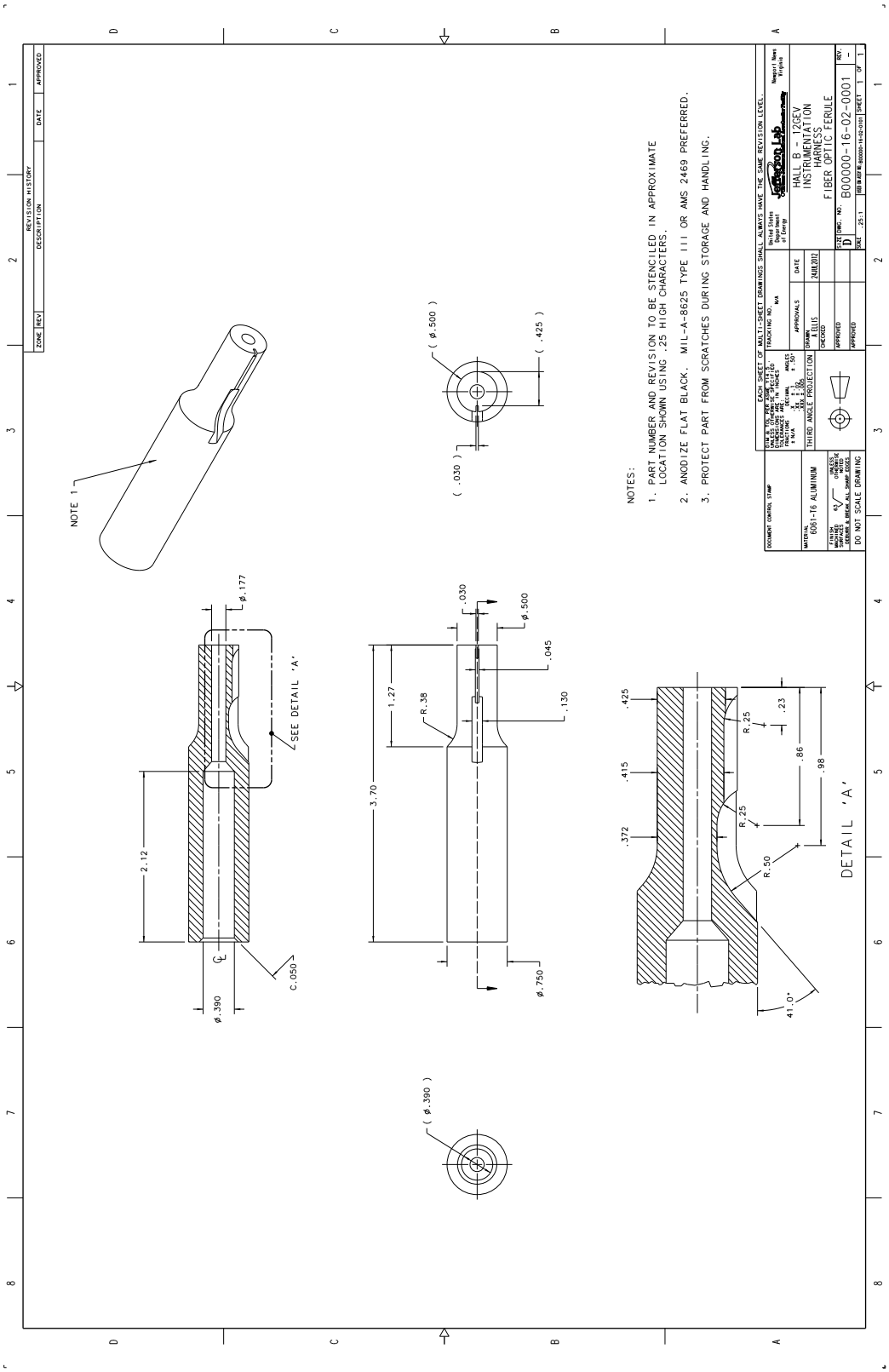

Figure 11: Fiber bundle harness for the HTCC LMS. Ref. Drawing B00000-16-02-0001.