Proposal to Install a PMT Flasher System in MicroBooNE

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1 Introduction and Motivation

In this note we describe a proposed PMT calibration system for microboone which utilizes 32 optical fibers coupled to LEDs to calibrate the experiments photomultiplier tubes. There are several motivations for installing such a system.

First, at many stages during detector construction it will be very useful to be able to check that each PMT assembly is connected and working. The flasher system offers a quick way of checking that each PMT cable is connected, each tube is still housed in its mount, still capable of receiving high voltage and still able to detect photons with the expected gain. This test performed for all PMTs is expected to take a few hours and will likely be performed directly after flasher installation, after TPC roll-in, after the cryostat is welded closed, after transportation to LArTF and after the first argon fill, to name but a few occasions.

The system is also a valuable calibration tool, greatly simplifying several technically complicated calibration procedures which have been envisioned for the PMT system. By using equal fiber lengths and including the ability to pulse all LEDs simultaneously, the PMTs can be timed in to one another with a precision of a few nanoseconds. By producing the calibration pulse simultaneously with a beam trigger, the TPC and PMT readout system timing can be aligned to each other with similar few-nanosecond precision. The alternative scheme of timing in the system based on reconstructed physics objects requires significant reconstruction machinery to be run on real data before the system can be properly calibrated, and the nontrivial distribution of photon times-of-flight created by effects such as Rayleigh scattering and surface reflections are likely to introduce a significant systematic error.

By choosing LED voltages low enough to produce only a single photoelectron pulse, the gain of each PMT can be monitored continuously during an experimental run. This technique has proven useful in monitoring gain stability in the Bo vertical slice test, being favored over the alternative late-light based method for several reasons. Evidence of gain suppression following large scintillation deposits at the few percent level suggests that single photoelectron sizes measured using late light may be biased to lower sizes. And the expected high late-light scintillation yields and long shaping time used in MicroBooNE make it more difficult to isolate single photoelectron pulses than was suggested in early lower purity argon test stands using direct readout of the PMT.

The flasher system also has potential applications in testing trigger logic. As well as the simple programs we describe in this document, the LED controller board can be programmed to produce non-trivial flash sequences on configurable combinations of PMTs, offering the opportunity to test trigger patterns, measure readout-system and trigger dead times and understand trigger timing.

The system we describe is designed to be as simple as possible, and have minimal interference with other experimental subsystems. The installation of the flasher system would take place after the PMT installation has been completed, and before the TPC is rolled into the cryostat. Once all parts are in hand, installation of the flasher into the detector is expected to take approximately three days - two days to install and one day to test that all channels are working. The logic used to control the flasher is designed to minimize any possibility of interference with physics data taking - the flasher does not have an internal clock, but produces a pre-programmed flash sequence when it receives an external NIM pulse. During commissioning, we can drive the flasher system with a signal generator to study the PMT system in situ. There are several options for supplying a NIM pulse to the flasher during physics data taking, which can be fully explored at a later date.

2 Cryostat Feedthrough

To feed fibers into the detector we propose to use a dedicated flange, which provides a compact way to bundle the fibers as they enter the cryostat. The fiber sections which are glued into the flange are only 25cm long, running from an optical patch panel on the outside of the cryostat to an optical coupling on the inside of the flange. On the inside, a connector holding the long internal fibers is coupled. On the outside, LEDs are coupled to fibers directly at the optical patch panel. The overall optical flange design is shown in Figure 1. This design leads to minimal installation interference with other subsystems, thereby allowing flexibility in the installation schedule. It also allows for further upgrades of the external components such as the LEDs or driving the electronics without making changes with the fibers or feedthrough.

By using standard components wherever possible we try to reduce the cost as much as possible. However, several custom made parts are also required. These parts are described in this section, and CAD drawings of each are included in the appendix to this document. Fibers are bundled and fed through a custom made aluminum fiber holder set into a modified standard 2 3/4" CF flange (Figure 9). On the argon side only a short aluminum fiber holder (Figure 7) extends about one centimeter. Onto this fiber holder is screwed a connector with all the long, internal fibers attached (Figure 8). The grid of 6x6 fibers are aligned between the internal connector piece and the feedthrough, leading to an optical coupling of a similar quality to that in a standard optical SMA connector. The advantage of this design above using 36 individual SMA connectors is that the fibers can enter the cryostat in a small area and a single flange, compared to the single SMA mounting which would require many more CF connectors (only 4 SMA connections can be mounted onto a CF 2 3/4" flange).

The fiber holder is connected in a vacuum tight manner to the CF flange by Stycast glue. A dedicated glue box (Figure 12), sitting on the "air" side will allow the pouring of the Stycast. Experience with optical fiber feedthroughs in Bo and Luke as well as preparation of the PMT SHV feedthroughs has shown that sealing connectors with Stycast is practicable and provides vacuum tight connections. Once the Stycast has been set, the vacuum tightness of this flange will be tested in a chamber at PAB which has been used to test PMT feedthrough prototypes before it is installed in the detector.

The outer part of the CF flange is required to be light tight. To ensure this, we propose to weld a 1 1/4" pipe on the CF flange, extending about 50mm which will allow the mounting of the CF flange on the larger PMT feedthrough. Welded onto the pipe is a butt pipe sled fitting, widening the pipe diameter from 1 1/4" to 3". The 3" end will be welded on a flat plate, to allow the connection with a

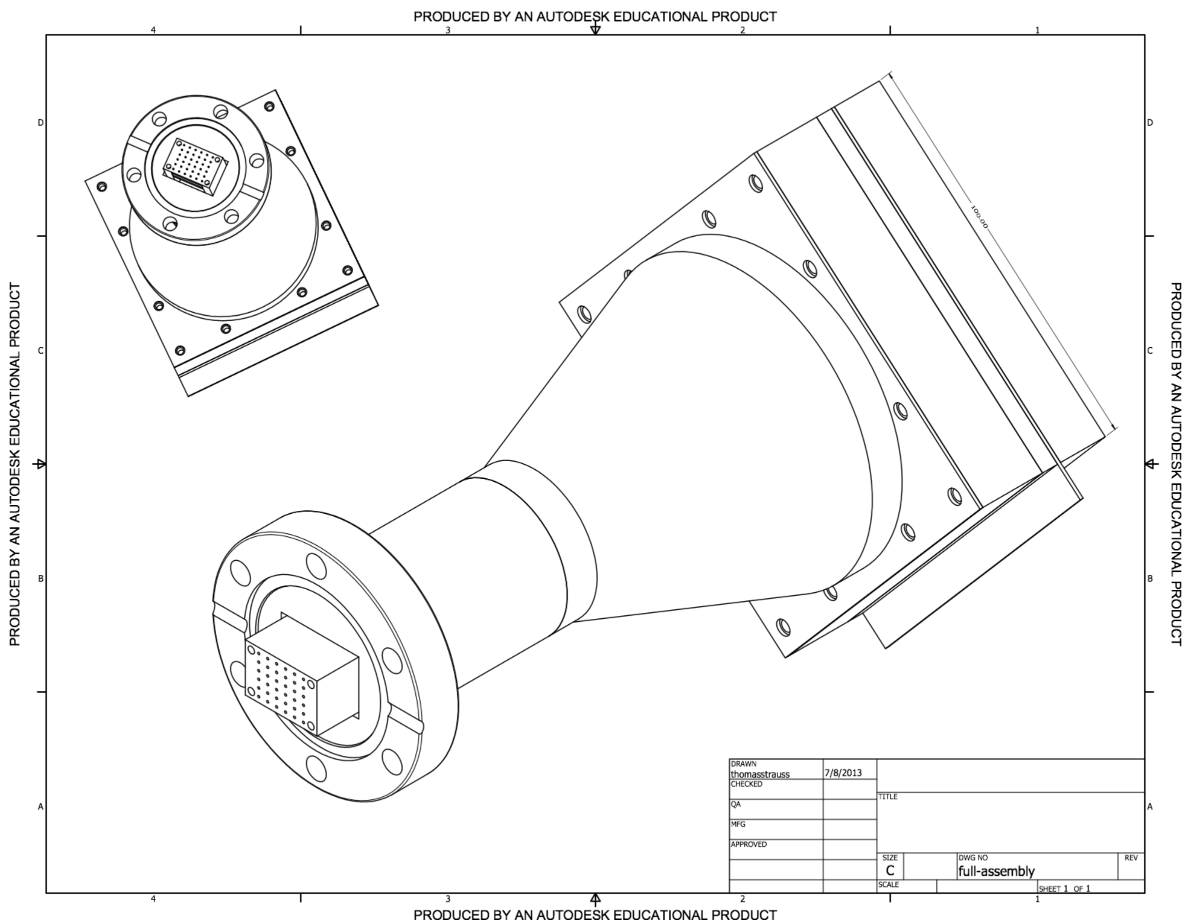


Figure 1: The cryostat optical fiber feedthrough for the PMT flasher system

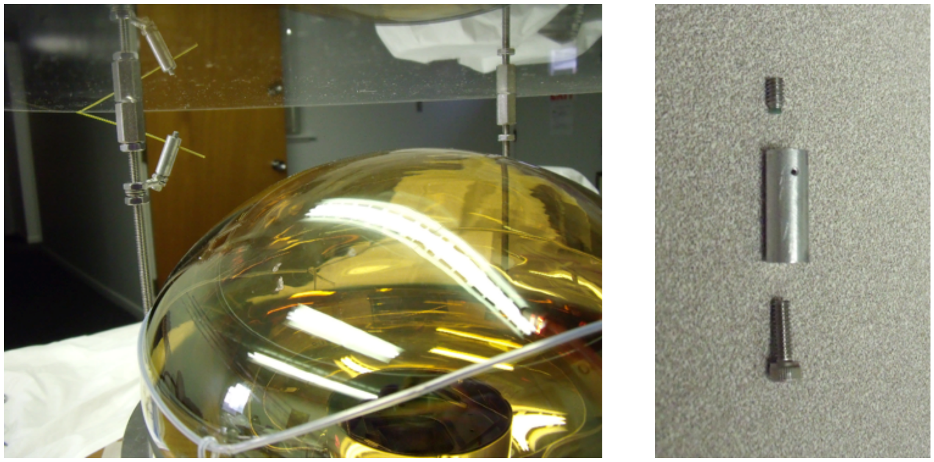


Figure 2: Left: Fiber mounting in situ on PMT mount, Right : custom piece being made at Nevis

fiber patch panel (Figure 10). This panel holds the splayed out fibers in a 6x6 grid, with 1cm spacing. 36 400nm surface mount LEDs are soldered onto a PCB LED board with this same spacing. Since the LEDs stick up from the board, a black plastic spacer section with 3mm holes aligned with each LED (Figure 13) is placed in between the LED board and the optical patch panel, with each hole sitting in front of one fiber and housing one LED. The whole structure to this point will be closed light tight with a black plastic end cap (Figure 11), which also protects the LED board. A further PCB board is required to drive the LEDs, and this and a second black plastic cover to protect the board are screwed down onto the top of the previously described stack. With this scheme, everything below the optical patch panel is permanently attached to the detector, whereas everything above including spacer, LED board, plastic cover, LED control board and plastic cover can be worked on or replaced after detector installation.

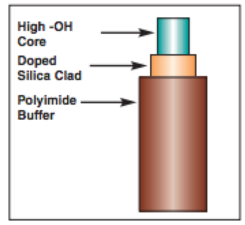
Several of the items can be procured from stock, and the simpler machined parts can be produced by DAB or PAB technicians. The 3 parts on which the fibers are mounted require more delicate work and should be done with a CNC machine at the Fermilab Workshop.

3 Internal Fiber Mounting Points and Fiber Routing

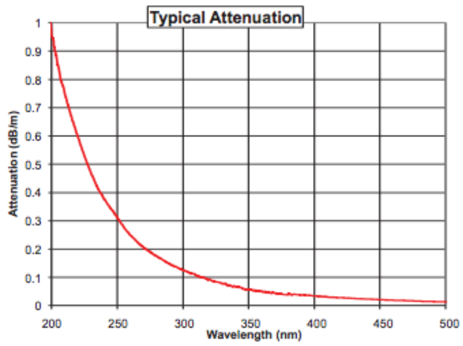
Fibers will be mounted to individual PMT assemblies, with the fiber being held in place in a stainless steel stand with a plastic-tipped set screw. This is shown in situ on a PMT mount in Figure 2, left. This mounting system is developed from components used in tried-and-tested mounts from the Bo and Luke cryostats at PAB. The fiber end will point at the PMT photocathode from underneath the wavelength shifting plate, approximately 2cm from the surface of the tube. The fiber holder is attached to the threaded rod which holds the TPB plate away from the magnetic shield via two round panduit clamps crimped together onto a 1mm threaded rod. One panduit clamp is held in place on the threaded rod by two nuts and a lock washer. The fiber stand is screwed into the other end. All parts of this mount are commercially available, with the exception of the fiber stands. These are currently being machined at Nevis laboratories and are expected to be shipped to Fermilab by 07/18/2013.

Fibers will enter through the same main flange through which the SHV cables for the PMTs run. Since their destinations almost the same, fibers will be routed along the PMT cables and attached using teflon ties, which are approved for use in various other places throughout the detector.

Product Descriptor	Core (µm)	Clad (µm)	Buffer (µm)
FDP100110125	100 ± 3	110 ± 3	124 ± 3
FDP200220240	200 ± 4	220 ± 4	240 ± 5
FDP400440480	400 ± 8	440 ± 9	480 ± 7
FDP600660710	600 ± 10	660 ± 10	710 ± 10



Note: The items listed in this table are standard configurations and sizes. Other configurations may be available on request. Please let us know what we can do to help satisfy your project requirements.



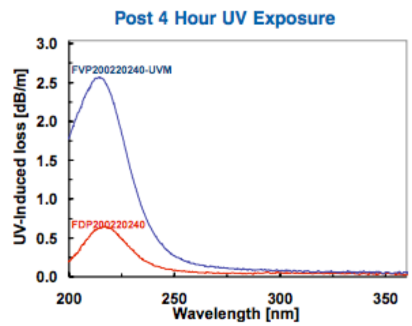


Figure 3: Specifications of the chosen optical fiber for the MicroBooNE flasher system

4 Optical Fibers

The flasher system uses 32 fibers, one running to each PMT, and four spare fibers in case of breakages during installation. Assuming all fibers survive, four PMTs will receive two sets of fibers, which may be useful for cross checking the simultanaety of calibration pulses. All fibers will be the same length, so that they can be used for timing calibrations of the PMTs. The cryostat is 10m long and our feedthrough is at the top of the open end. The internal fibers which run from the feedthrough to PMTs will be approximately 15m long each. A second set of 32 fibers is optically coupled to the internal fibers on the inside of MicroBooNE at the feedthrough. These fibers will be approximately 25cm long, with the exact length determined by the geometry of the final cryostat flange piece. The fibers will be routed along the PMT SHV cables and attached with teflon rope at several points along their path, with strain relief wherever possible. The system as described would require 489.6m of fibers for the 32 main fibers, or 550m including four spares.

The fiber of choice is a 600 μm silica core, doped silica clad and polymide buffered optical fiber which has been used extensively at PAB in the Bo and Luke cryostats both to run purity monitors and to operate LED flashers. The attenuation at 400nm is 0.05 dB/m which is easily low enough for this application. The fibers in Bo and Luke have been repeatedly cryo cycled and do not show any signficant fatigue or observable purity problems. Since they have no outer jackets, these fibers are very fragile so care must be taken during installation not to snag or kink any of the fibers.

An order has been placed with Molex for 550m of fiber which is due to arrive at DAB in two batches: the first 150m by 07/09/2013, and the remaining 400m by 08/09/2013. The internal fibers must be routed to the PMTs inside the cryostat between installation of the PMT assemblies and rolling in the TPC.

5 LEDs and Electronics

Driving electronics for the LEDs are based on a system which has been used to pulse LEDs for the Bo vertical slice test, extended to 36 channels and with a new controller board. The system is comprised of two PCB cards, mounted directly onto the feedthrough and connected by a 1 inch, 37 pin keyed ribbon cable. The LEDs and their driver circuits are mounted on the lower board, referred to as the "LED board". The brightness and timing of LED pulsing, as well as all communication of the system with the outside world is handled by the upper board, referred to henceforth as the "control board" The board mounting and cabling scheme has been designed under advisement from Linda Bagby, and the detailed board design will be handled by Sten Hansen at Fermilab. USB communication to nearby DAQ machines has been chosen with agreement from Eric Church.

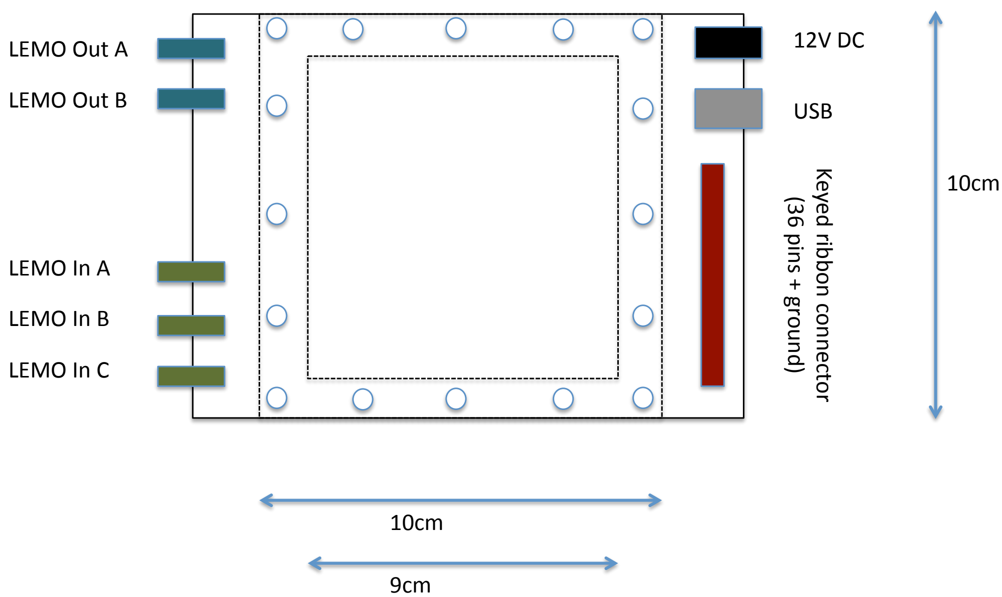


Figure 4: Cartoon showing the layout of the LED control board.

5.1 LED Board

The LED board has components on two sides. On the lower side are 36 LEDs spaced in a 6x6 grid with 1cm spacing which align with fibers on the optical patch panel. On the reverse side of the board are 36 LED driver circuits, which are based upon the "postage stamp" LED boards which have been used at PAB. The driver circuits each receive a DC bias voltage from the pins of the ribbon connector which determines the bightness of the LED flash. A flash is initiated when the driver circuit receives a short 1ns pulse, provided on the same pin as the DC bias, from the control board. The 37th pin on the ribbon connector gives a common ground to all driver circuits. A schematic of the underside of the LED board is shown in Figure 5. One driver circuit is shown in Figure 6. The underside of the LED board fits snugly onto a drilled black plastic spacer which has 3mm holes in the position of each LED. This spacer sits between the fiber connector and the LED board and ensures that each LED has a good optical coupling to its fiber and that each LED does not produce light visible by any other fiber. The board is covered by a black plastic housing screwed down onto the top side. The cover, LED board, spacer and fiber connector will be screwed down tightly using 16 screws

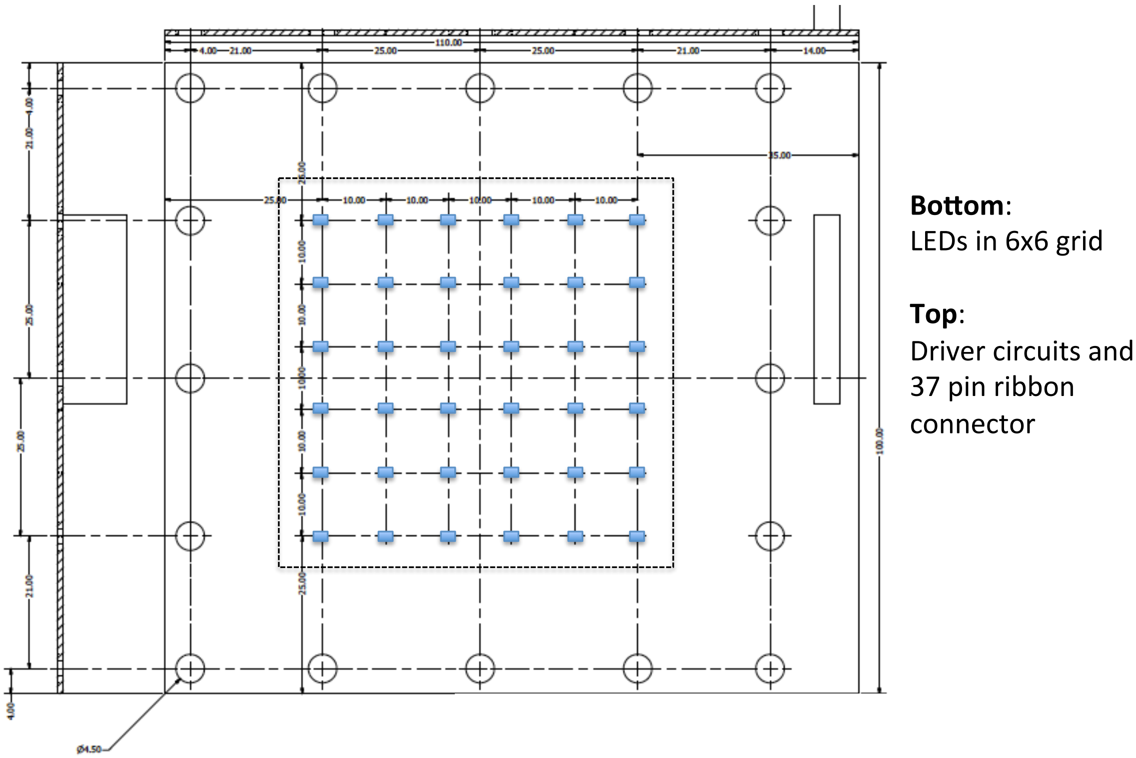


Figure 5: Schematic of the LED board

5.2 Control Board

The control board supplies the DC voltages and the pulses to fire the LEDs. The technical design is still in progress, but the functionality is as follows: The board is connected to the LED board by a keyed ribbon connector. 12V DC is supplied by an incoming DC supply line. The offset voltages on each pin of the ribbon can be chosen to be between 0 and 12V, programmable via USB. A usb cable runs ~2m to the computer uboonedaq_prod_platformpmt which is a PC sitting in the PMT rack.

The board is instructed to pulse via one of two LEMO cables, which accept NIM pulses. LEMO A initiates a simultaneous 1ns pulse on every LED channel. This mode is used for timing calibration. LEMO B initiates a sequence where each LED is pulsed in succession, from 1 to 36, with a 200ns gap. A trigger out LEMO is also included, so that the board firing can be indicated to the PMT trigger. With this design choice, the board fires only when it receives an external command to do so, and so we avoid having to time in a clock with the beam gate and risk interfering with real data taking. The exact source of the NIM pulse can be determined at a later date, and commissioning and calibration runs can be performed with a simple signal generator. A simple scenario for future calibrations between beam gates may involve a delay module creating NIM pulses offset by a constant time interval from the beam trigger signal. Spare LEMO inputs and outputs have been requested on the board, and may be programmed at a later date. A cartoon of the board is shown in Figure 4, and a more detailed design is in progress.

6 Appendix: CAD drawings of custom feedthrough parts

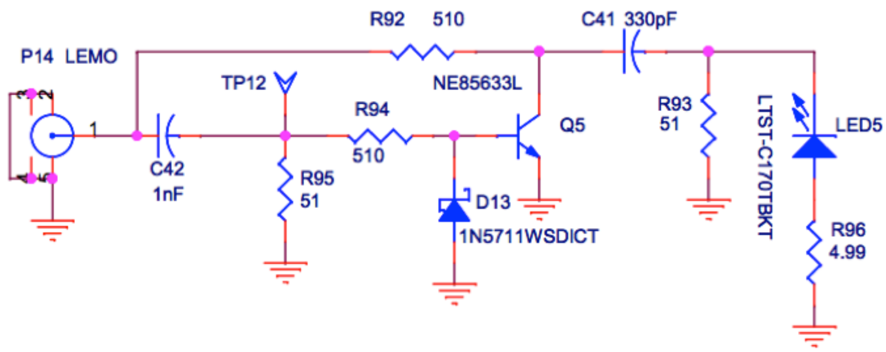


Figure 6: Circuit diagram for one LED driver circuit

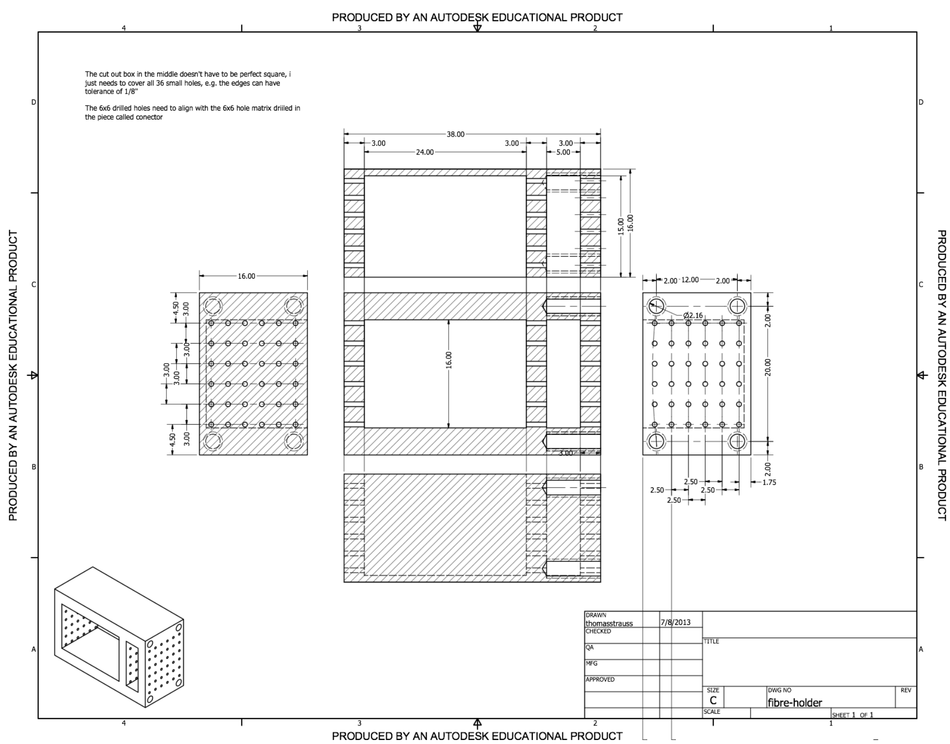


Figure 7: Fiber holder

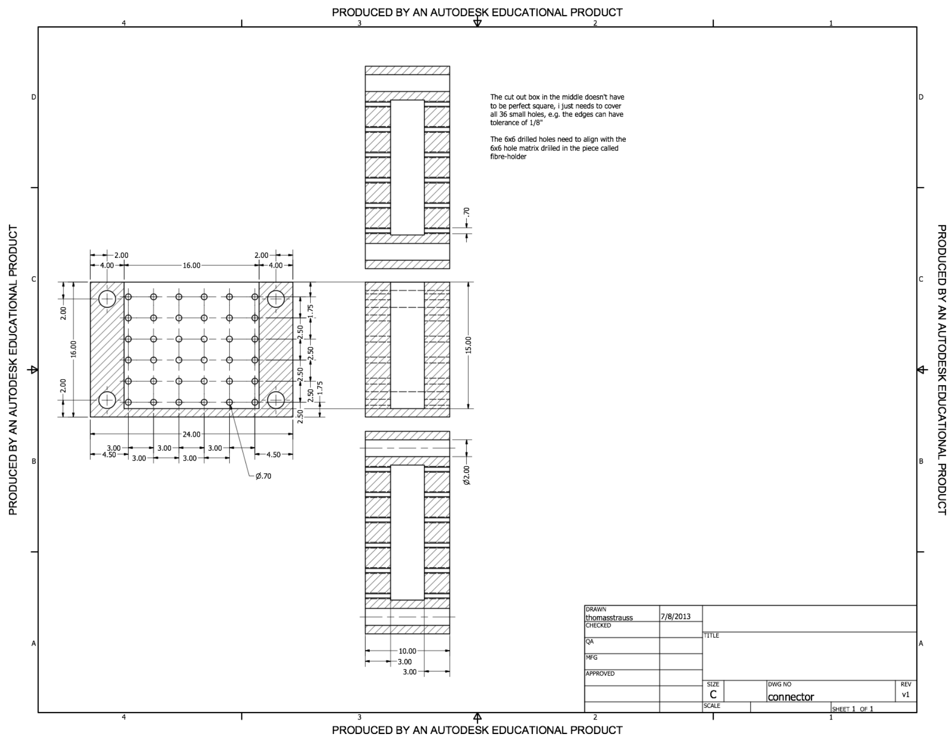


Figure 8: Internal fiber connector

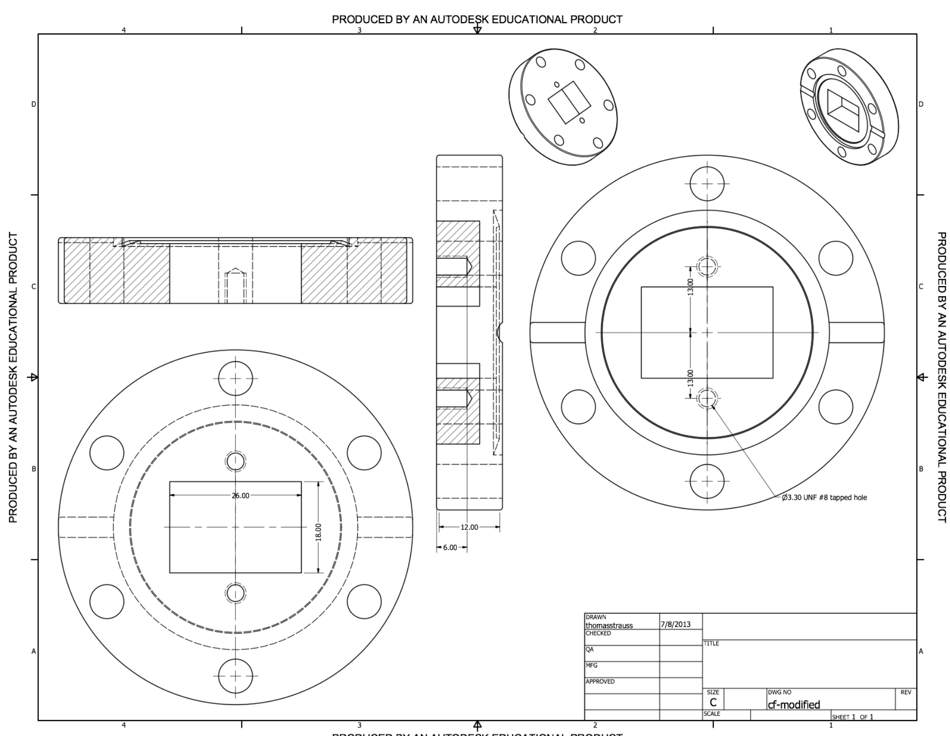


Figure 9: Modified CF flange

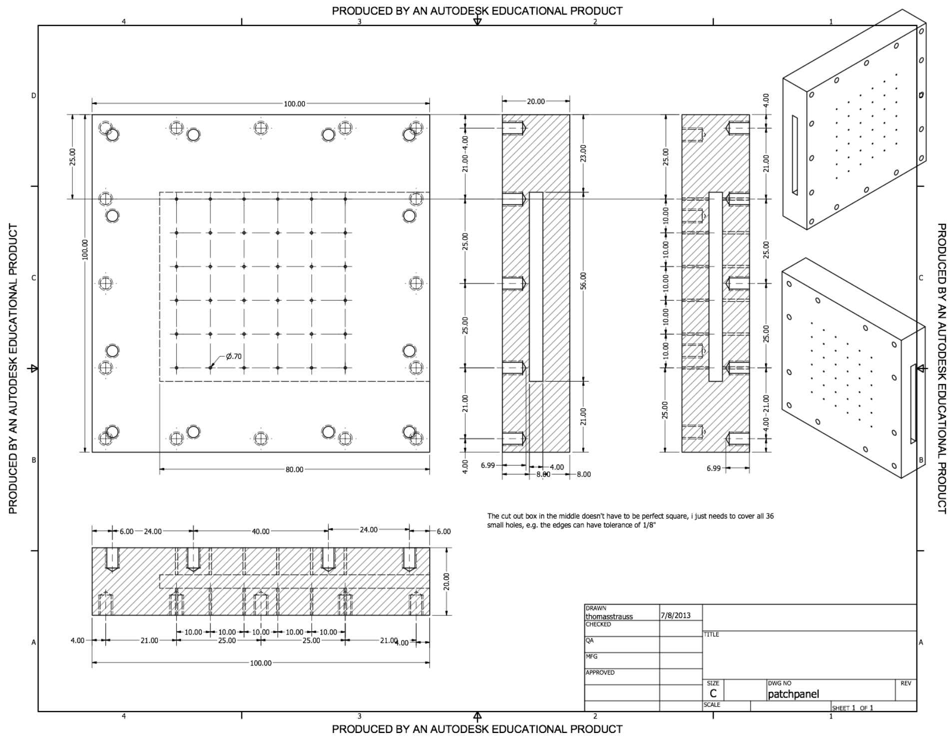


Figure 10: Optical patch panel

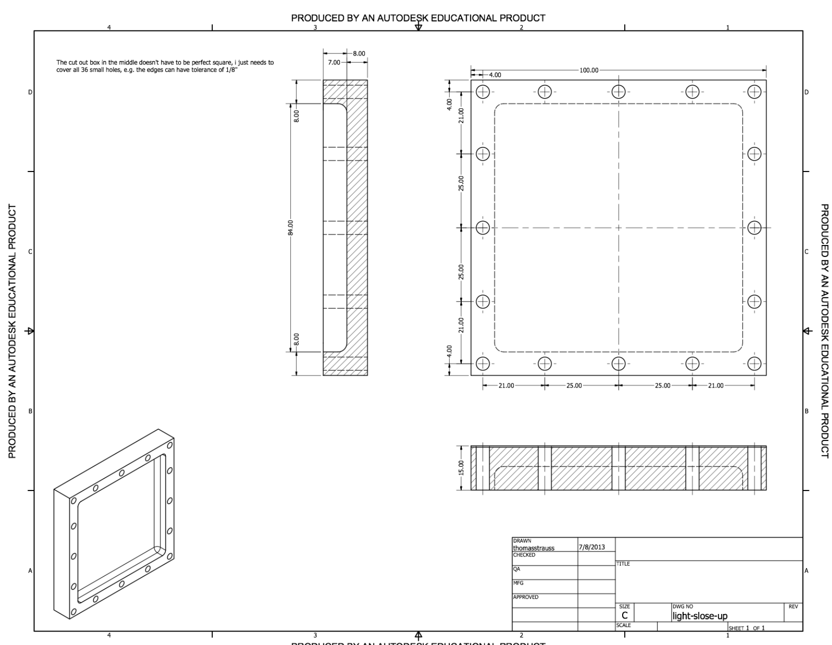


Figure 11: PCB cover

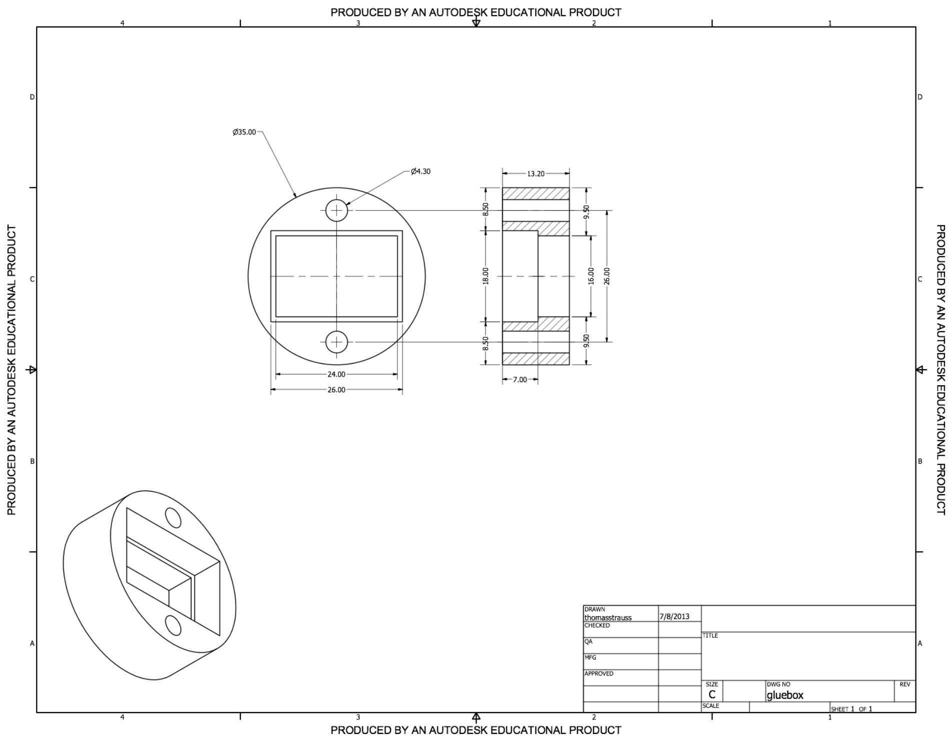


Figure 12: Glue Box

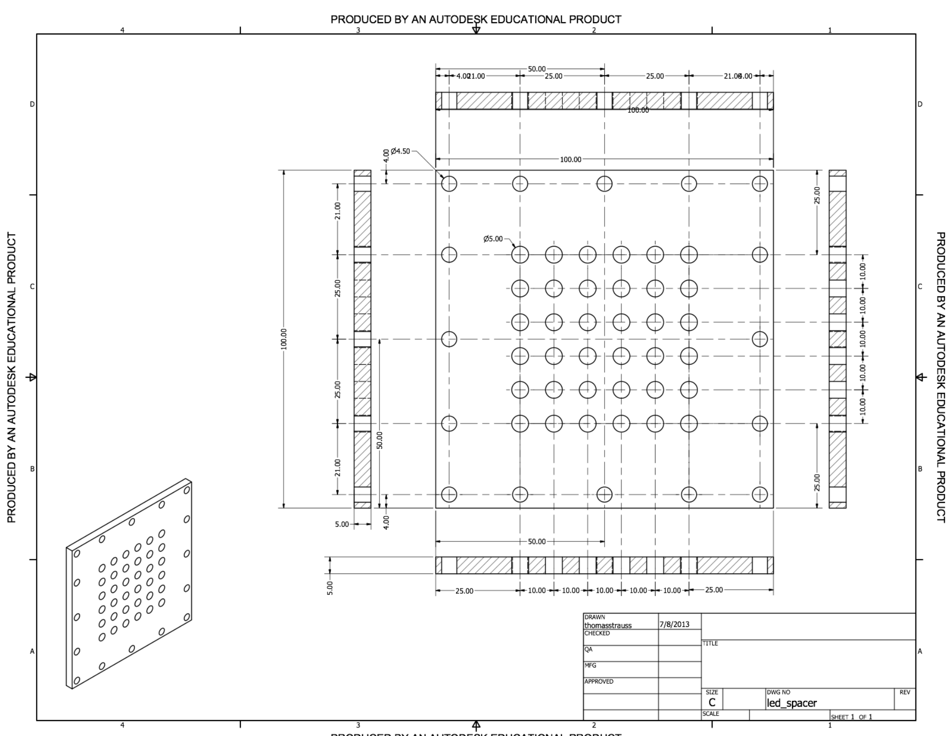


Figure 13: LED Spacer