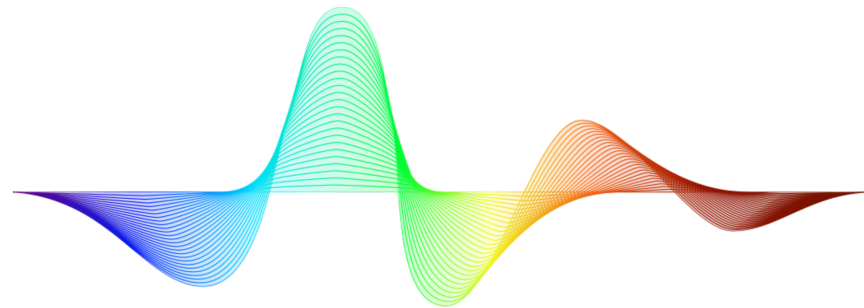

BENCHTOP LIDAR SYSTEM (BLS200)

INSTRUCTION MANUAL

Eddie Ruff
Research Engineer
Exciting Technology LLC
Dayton, OH 45469
eddie@excitingtechnology.com

Cullen Bradley
Research Operations Manager
Exciting Technology LLC
Dayton, OH 45469
cullen@excitingtechnology.com

February 7, 2020



E X C I T I N G
T E C H N O L O G Y

Proprietary Statement: This instruction manual summarizes Exciting Technology's (ET) Benchtop LiDAR System (BLS200). The information in this document is not to be disclosed outside of the user testing facility and shall not be duplicated, used, or disclosed-in whole or in part-for any purpose unless explicit permission from ET has been obtained. The information subject to this restriction are contained in pages 1-22.

About Exciting Technology

Exciting Technology (ET) is a research company founded by Dr. Paul F. McManamon in 2008. We are currently located in Dayton, Ohio.

Dr. McManamon started ET after he retired from being Chief Scientist for the Air Force Research Lab, AFRL, Sensors Directorate.

Please navigate to our website to learn more: <https://excitingtechnology.com/>

Contents

1	Safety Warning	5
1.1	Laser Radiation	5
1.1.1	Internal Radiation	5
1.1.2	External Radiation	5
1.2	ESD Caution	5
2	System Components	7
2.1	Layout Overview	7
2.2	BLS200 Optical Configurations	9
2.3	Optional Sensors	10
2.4	External Monitoring	10
2.5	Required Tools, Cables, and Adapters	11
3	Getting Started	12
3.1	Free-Space Operation <200m	12
3.2	Fiber-based Operation	12
3.3	Power Connections	12
3.4	Output Monitoring	13
4	Calibration	14
4.1	Optical Alignment	14
4.1.1	Fiber Coupling Laser Output	14
4.1.2	Verifying the Optical Power	14
4.1.3	Aligning the Transmit & Receive Apertures	14
4.1.4	Aligning the Sensor	16
4.2	Electrical Adjustment	17
4.2.1	Pulse Characteristics	18
4.2.2	Verifying Pulse Clock Signal	18
4.2.3	Pulse Trigger Adjustment	18

4.2.4	Verifying Trigger Pulse and START Pulse	19
4.2.5	Return Pulse Conditioning	19
5	Troubleshooting	20
5.1	Why is there no laser output?	20
5.2	Why do the Start and Stop Monitor outputs not work?	20
5.3	Why is the Time of Flight (ToF) readout incorrect?	20
5.4	Why is there no return pulse?	20
5.5	How do I change the sensor?	21
5.6	How do I align the sensor?	21
5.7	How do I connect a single-ended sensor?	21
5.8	How do I connect a differential sensor?	21
5.9	I cannot obtain a return pulse.	21
5.10	I think I broke something.	21
6	Warranty	22

1 Safety Warning



Figure 1: BLS200 contains and emits laser radiation.



Figure 2: BLS200 contains ESD susceptible components.

1.1 Laser Radiation

The BLS200 uses a 905nm laser diode (listed in Table 1). Recalculating the Peak Energy Density is necessary for any wavelength or power modification (i.e. using a different laser diode).

1.1.1 Internal Radiation

The following pulse and power characteristics exist INSIDE the BLS200 before fiber coupling. While the Laser PCB significantly diverges the laser light, there is a small focused region of light before fiber coupling which should be avoided as it is not eye safe.

- Pulse Repetition Rate of 10KHz
- Beam Diameter <1mm
- Pulse width (FWHM) between 8ns and 100ns
- Average power <6mW
- Peak Power Density < 3321.5 W/cm^2
- Peak Energy Density for 46ns exposure < $1.527e-4 J/cm^2$ → **NOT EYE SAFE!**

1.1.2 External Radiation

The following pulse and power characteristics exist OUTSIDE the BLS200 after the transmit aperture. To maintain eye-safe operation, the following pulse and power characteristics must be utilized.

- Pulse Repetition Rate of 10KHz
- Transmit Aperture >12.5mm
- Pulse width (FWHM) between 8ns and 100ns
- Average fiber coupled power <3mW
- Peak Power Density < 50.92 W/cm^2
- Peak Energy Density for 46ns exposure < $4.07e-7 J/cm^2$ → **EYE SAFE!**

The Maximum Permissible Exposure (MPE) for eye-safe operation is depicted in Fig.3.

1.2 ESD Caution

Several electrical components are susceptible to electrostatic shock and discharge. Always use an insulated adjustment screwdriver when adjusting trim potentiometers. Component and system failure can result from ESD.

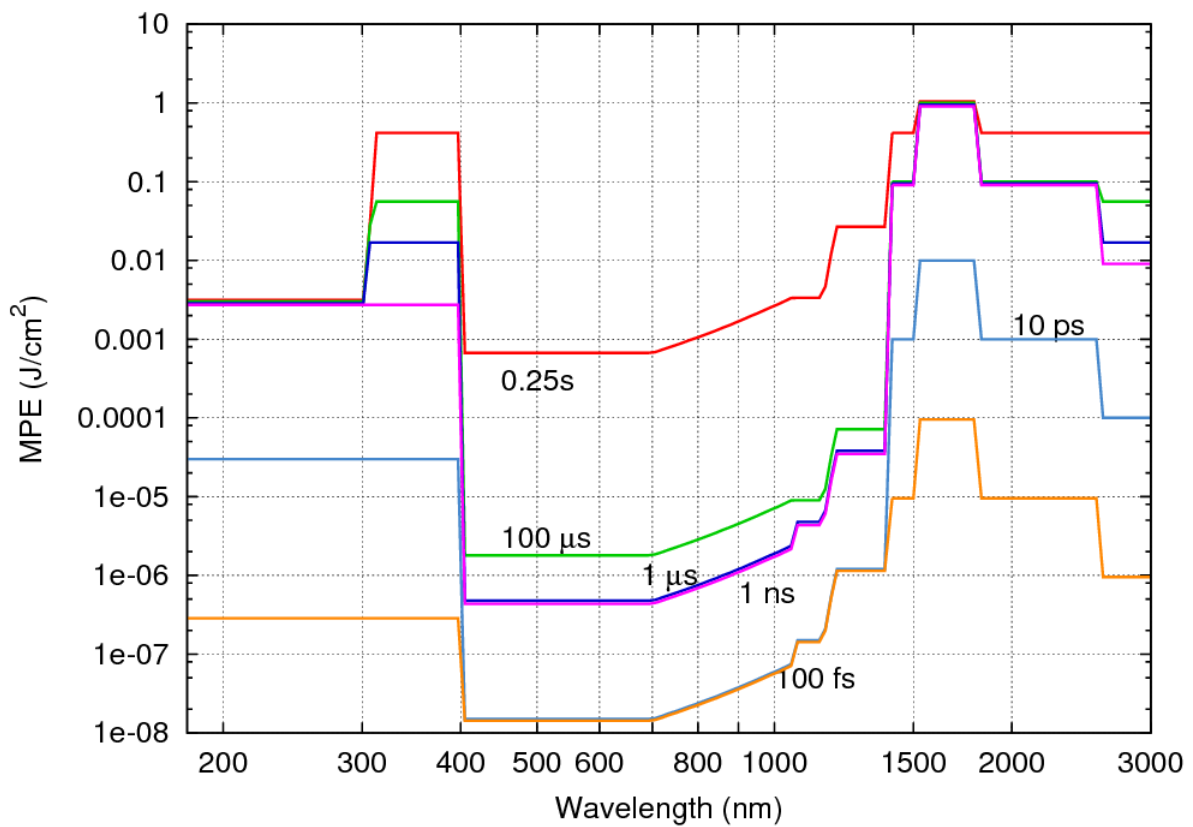


Figure 3: MPE for Eye Safe operation.

2 System Components

The BLS200 is mounted on an aluminum optical breadboard. Inside, you will find a very simple optical and electrical layout. First, the LiDAR eVal PCB provides the required voltages and signals to the Laser PCB. A Surface Mount Design (SMD) laser diode centered around 905nm is incident on a fiber collimating lens. The laser light immediately after the Laser PCB is diverging. This light fills the lens which then focuses the light into the white 99% fiber. The white fiber then connects to the transmit aperture which sends the laser light into free space propagation. The return light is collected by the receive aperture and focused onto the sensor under test.

Table 1 below lists all the required system components for the BLS200 .

Component	Manufacturer	Function	Voltage Requirements
LD Driver C14364*	Hamamatsu	Laser PCB	$V_s = 15V$, $V_c = 32V$
Pulsed Laser Diode L4075-01*	Hamamatsu	SMD Laser Diode 905nm	$V_{th} = 7V$, $V_c = 32V$
MPPC Driver C14191**	Hamamatsu	MPPC PCB	$V_s = \pm 5V$
MPPC S13720**	Hamamatsu	MPPC Sensor	$V_{breakdown} = 60V$
LiDAR eVal PCB	Exciting Technology	PSU, Pulse Gen, ToF PCB	$V_s = 12V$
Optical Breadboard	Thorlabs	Enclosure & Stages	
Transmit & Receive Apertures	Thorlabs	Tx & Rx Apertures	
APD eVal Board**	Excelitas	Sensor PCB	$V_s = \pm 5V$, $V_{HV} = 225V$
APD C30902EH**	Excelitas	APD Sensor	$V_{breakdown} = 225V$
MicroRB-10020**	SensL	MPPC Sensor	$V_{breakdown} = -23V$
MicroRB-SMA-10020**	SensL	MPPC PCB	$V_s = -23V$
APD S12926-05F**	Hamamatsu	APD Sensor	$V_{breakdown} = 159V$
APD S13282-01CR**	Hamamatsu	APD Sensor	$V_{breakdown} = 159V$
C13283 eVal Board**	Hamamatsu	APD PCB	$V_s = 3V$, $V_{HV} = 159V$

Table 1: System Components for the BLS200

* *Not included, but a laser diode and driver is required for system operation.*

** *Optional sensors and PCBs for testing*

2.1 Layout Overview

The BLS200 is a mobile unit equipped with carrying handles as depicted in Fig.4. The optical breadboard enclosure sits on four rubber feet and features removeable cardboard walls and lid which can also be utilized as calibrated targets (TB4 Black Hardboard). The TB4 hardboard reflectance is shown in Fig.5. The enclosure dimensions are 18" x 16.5" x 12" (Length x Width x Height). The total weight is approximately 35 lbs.

Removing the four lid screws located in each corner provides access to the inside of the enclosure. You will need to use a 1/8 inch hex driver to remove the lid screws. Fig.6 depicts a top down view once the lid has been removed. Notice the optical layout on the left and the LiDAR eVal PCB on the right.

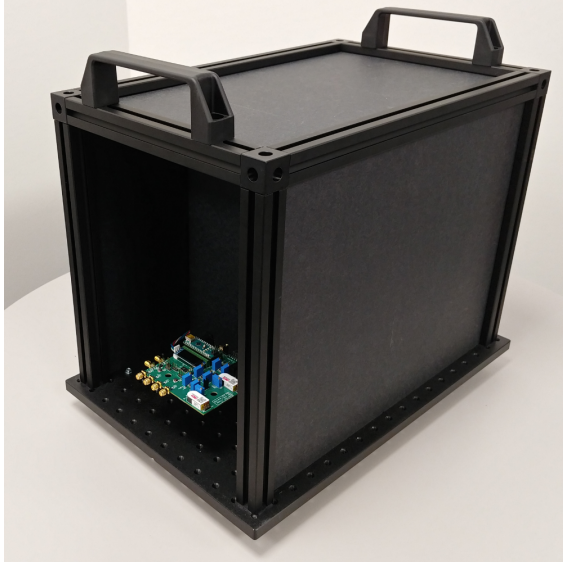


Figure 4: The BLS200 Enclosure with carrying handles & removeable TB4 hardboard sides.

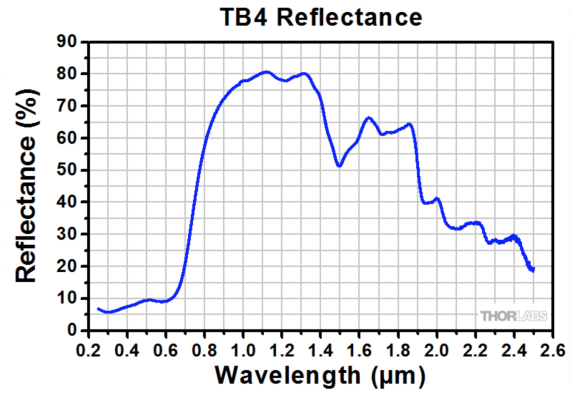


Figure 5: Reflectance of TB4 Hardboard. Courtesy of Thorlabs.

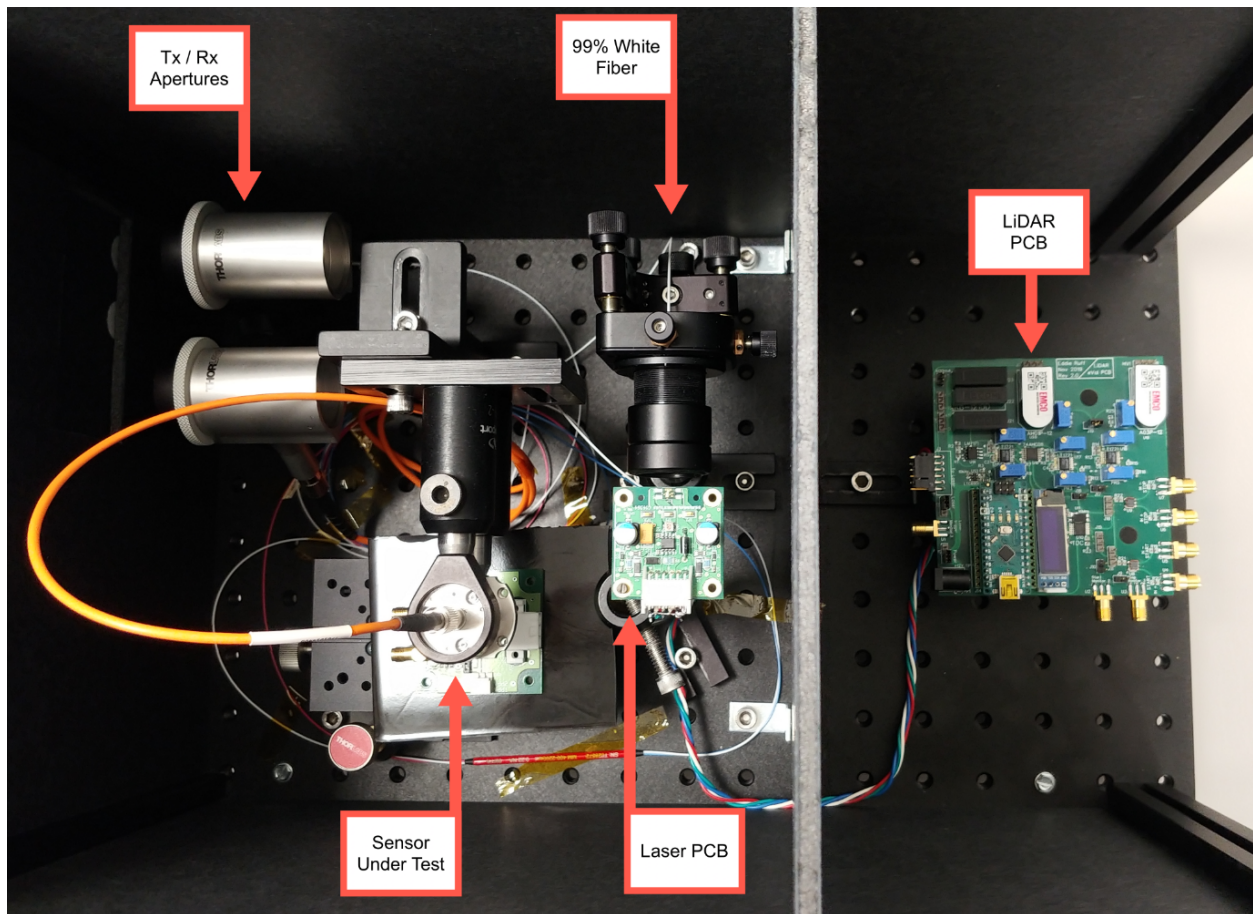


Figure 6: The BLS200 Top-down view. Left - Optical system. Right - LiDAR eVal PCB

2.2 BLS200 Optical Configurations

The BLS200 can be configured for either free-space or fiber-based testing. Fig. 7 depicts the fiber-based configuration while Fig. 8 depicts the free-space configuration. The free-space system is useful for testing different range and target(s) scenarios. The fiber-based configuration is useful for sensor comparison with precise power control.

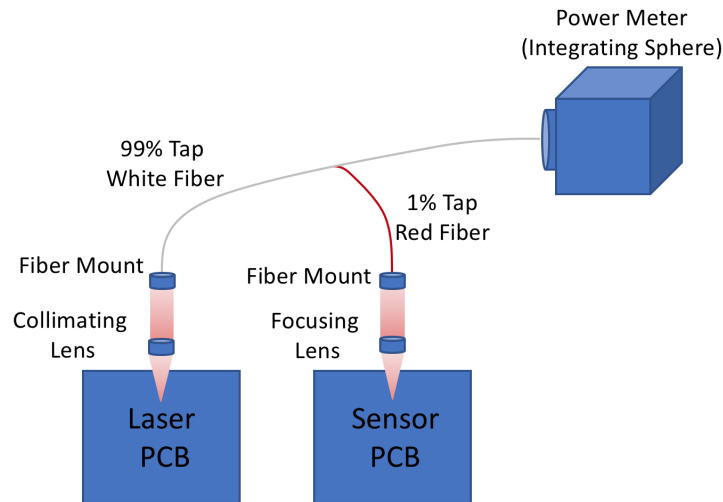


Figure 7: The BLS200 Fiber-based Configuration

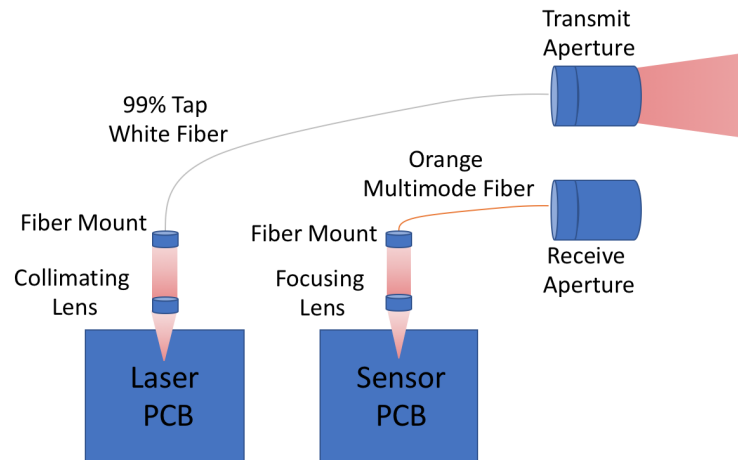


Figure 8: The BLS200 Free-space Configuration

2.3 Optional Sensors

The BLS200 is intended to test several different APD and MPPC sensors. Four different sensors have been tested with this particular version. Figures 9 - 12 depict the four sensors. Each sensor requires unique power requirements and output monitoring. For example, different breakdown voltages and single-ended versus differential output monitoring. The LiDAR eVal PCB rev2.0 cannot accommodate a negative voltage supply which is required for the SensL MPPC. Future revisions to the LiDAR eVal PCB will include an adjustable negative voltage supply.

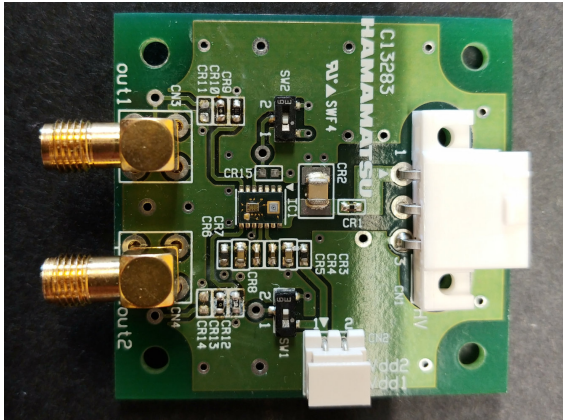


Figure 9: Hamamatsu APD

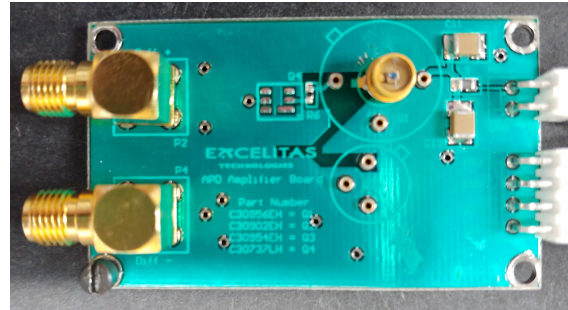


Figure 10: Excelitas APD



Figure 11: Hamamatsu MPPC

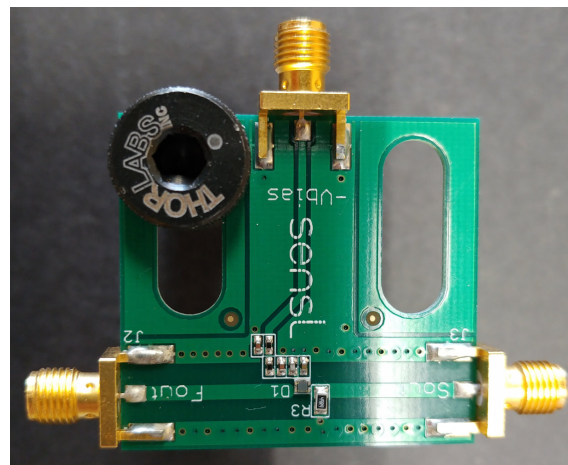


Figure 12: SensL MPPC

2.4 External Monitoring

To gain more insight into the system calibration and performance, additional external monitors can be utilized. A Keysight DSO-X 3012T oscilloscope (pictured in Fig. 13) is sufficient for resolving the temporal features of the pulse signals and LiDAR returns. This particular oscilloscope features a 100MHz analog bandwidth and 5GSa/s digital sampling.

A Thorlabs S145C integrating sphere (pictured in Fig. 14) can be connected to the white 99% fiber tap or the red 1% fiber tap in order to monitor the laser power (with the included S120-FC Fiber Adapter from Thorlabs). This allows the user to adjust the laser alignment for maximum power output and coupling efficiency. The integrating sphere is responsive from 800nm to 1700nm with a 1 μ W to 3W power range. The power meter must be connected to a Thorlabs PM100USB interface (also pictured in Fig. 14) in order to view the measured power. A laptop with an available USB port can be utilized in addition to the provided monitoring software. Be sure to enter appropriate laser wavelength in the monitoring software or the measured values will be inaccurate.

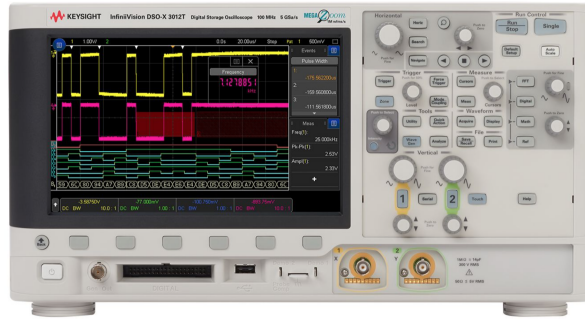


Figure 13: Keysight DSO-X 3012T 100MHz 5GSa/s



Figure 14: Thorlabs S145C Integrating Sphere and PM100USB interface

2.5 Required Tools, Cables, and Adapters

The BLS200 LiDAR eVal PCB features Bourns 3296 Trimmer potentiometers. These can be adjusted with a small flathead screwdriver but we recommend purchasing a Bourns H-91 screwdriver for easier adjustability (pictured in Fig. 15). It should be noted that the cycle life of these trimmer devices is <200 cycles. Therefore, we recommend infrequent adjustment otherwise component failure could result. These parts can be replaced or even substituted for a more robust potentiometer.

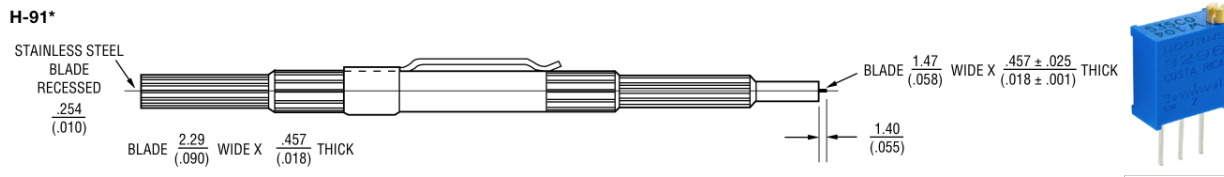


Figure 15: Required Electrical Tools - a Bourns H-91 screwdriver for adjusting the blue 3296 trimmer potentiometers

The optical components primarily utilize a 1/4 inch socket head cap screws which require a 3/16 inch hex driver. Some assembly screws require a 1/8 inch hex driver, for example, the 4 lid screws in each corner.



Figure 16: Required Optical Tools - a 3/16 inch hex driver and 1/4 inch socket head cap screws. (Not pictured - a 1/8 inch hex driver is also required)

3 Getting Started

The BLS200 can be configured for free-space or fiber-based operation. Free-space operation allows the system to emit pulses down range and receive return signals from targets <200m away. The fiber-based configuration does not emit any pulses down range. This setup uses a 1% fiber tap to emit pulses directly onto the sensor. The fiber-based sensor testing is more consistent for sensor to sensor comparisons as the power can be easily controlled and tuned to the desired output.

3.1 Free-Space Operation <200m

Free-space operation will enable the BLS200 to emit pulses down range to targets <200m. The Laser PCB should couple into the 99% white fiber tap. This fiber then connects to the Transmit aperture. The multimode orange fiber connects to the Receive aperture and then to the sensor alignment optics. The blue and red fibers should be capped and unused. The system is now configured for free-space operation. Proceed to the power connection section.

3.2 Fiber-based Operation

Fiber-based operation will prohibit the BLS200 from emitting laser pulses outside of the enclosure. The Laser PCB should couple into the 99% white fiber tap. This white fiber then connects to a power meter for monitoring purposes. The red 1% fiber should then be connected to the sensor alignment optics. The transmit and receive apertures are unused. The blue and secondary white fibers should be capped and unused. The system is now configured for fiber-based operation. Proceed to the power connection section.

3.3 Power Connections

The BLS200 is equipped with a LiDAR eVal PCB which powers the laser, sensors, and computes the Time of Flight (ToF) measurements. The LiDAR eVal PCB requires a 12V DC power supply where the **center tip is +12V**. The power supply should be rated for 2000mA current consumption. With no external loads attached, the power consumption is approximately 1.5W (12VDC at 126mA).

First, ensure the high voltage potentiometers are rotated fully **counter clockwise (CCW)**. These pots are located at PR4, PR5, and PR6 on the right side of the PCB in Fig.22.

Next, ensure the high voltage switches are set to the OFF position. These switches are located at SW3, SW4, and SW5. The OFF position is when the red slider is in the rightmost position.

With the wall-plug disconnected, insert the DC jack into the P1 port as depicted in the upper left corner of Fig.22.

The LiDAR eVal PCB board will only turn on when the power switch (SW1) is in the ON position. This switch is located in the upper left near P1. The ON position of SW1 is when the red slider is in the rightmost position.

An external power switch can be connected to the SW1 PCB through-holes. The rightmost through-hole is connected to the ground plane should an external power switch require a ground reference.

Once you have disabled the High Voltage section and made the appropriate P1 connection, plug the wallplug in and the LiDAR eVal PCB should turn on. The Arduino indicator lights should be active. The OLED display should begin the startup sequence and then depict the calculated ToF measurements. When the laser is OFF or no STOP signal is detected, the display should read 0.00m. If no START signal is detected the display will read NaN for Not a Number.

The laser should be off so long as the red slider of SW2 (Laser Switch) is in the rightmost position. This prevents the laser pulse from going to the H1 header which then goes to a laser PCB. Regardless of the SW2 position, you can still measure the outgoing pulse via SMA1 (Laser Pulse Monitor 1).

The LiDAR eVal PCB provides several voltage outputs. H2 features $\pm 5V$ at $\pm 200mA$, H3 features $\pm 15V$ at $\pm 66mA$, H4 features $+5V$ at $400mA$. There are three adjustable high voltage (HV) supplies located at H5 ($+100V$), H6 ($-100V$), and H7 ($+300V$). The HV supplies can be individually enabled/disabled via SW3, SW4, and SW5. Adjusting PR4, PR5, and PR6 changes the voltage at H5, H6, and H7 respectively. Adjusting the potentiometer clockwise (CW) increases the output voltage. Adjusting the potentiometer counter-clockwise (CCW) decreases the output voltage.

For adjusting the High Voltage, we recommend starting from a fully CCW position and gradually raising the voltage only when an appropriate load is connected. **The HV supplies must have a load connected at all times.** We've included a $1M\Omega$ load to prevent over-voltage and damage to the HV supplies as depicted in Fig.17.

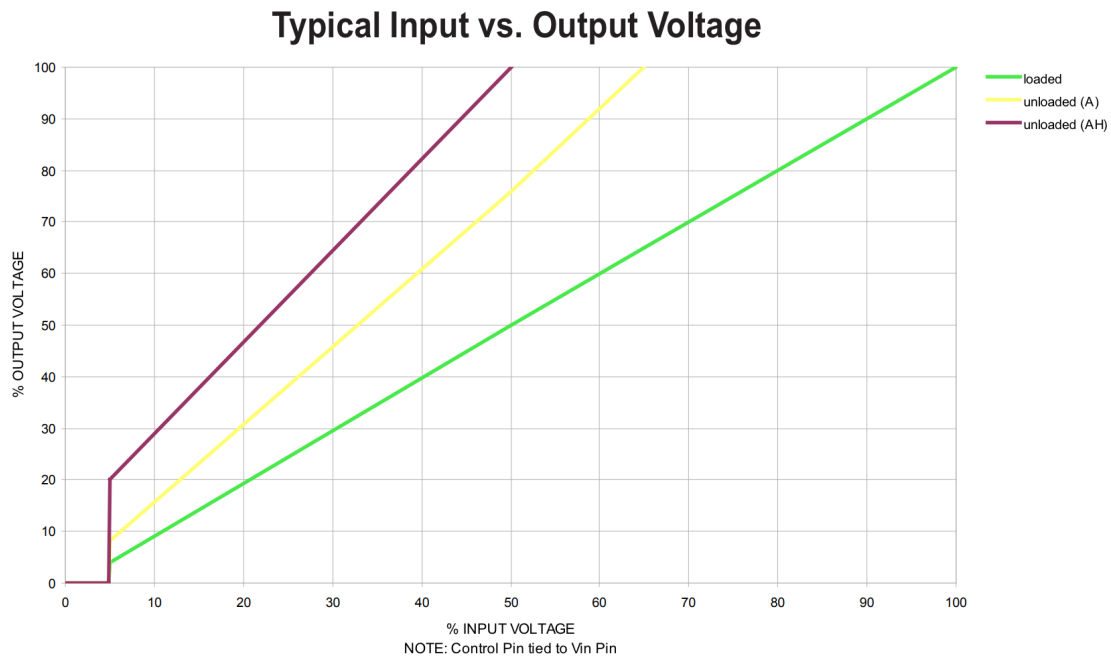


Figure 17: **WARNING:** The included High Voltage Supplies require a load at all times. The output Voltage is load dependent. Under light or no-load conditions, reduce the Input Voltage so the maximum rated Output Voltage is not exceeded.

NOTE: H5 feeds pin 2 of H1 in order to supply the Laser PCB with a charge voltage $<50V$ (depending on the laser). The Laser PCB should be connected when adjusting PR4. Monitor the voltage with a multi-meter or oscilloscope.

3.4 Output Monitoring

The START and STOP pulse signals from external optical sensors can be monitored via an oscilloscope connection with a $1M\Omega$ termination. These monitor ports are located at SMA2, SMA3, SMA4, SMA5, and testpoint TP2 and TP3 can also be utilized.

SMA2 and SMA3 are directly connected on the PCB. Similarly, SMA4 and SMA5 are connected. This allows the user to split the incoming raw sensor signal so that an external oscilloscope can be used for monitoring.

The START signal can be an electrical pulse or an optical pulse. We recommend using an electrical pulse that way you can avoid the use of an additional optical sensor. **SMA2 and SMA3 should only be utilized if an optical START pulse is connected. Otherwise, use SMA1 to monitor the amplified Electrical START Pulse.** The STOP signal is generated by the optical sensor under test.

The built in electrical START Pulse can always be monitored via SMA1. This should also be a $1M\Omega$ termination as the signal can be $>10V$ and is designed to drive the laser PCB. There will be oscilloscope ringing from the improper termination. If you provide a proper 50Ω termination, the pulse will look great on the oscilloscope, but the laser

PCB might not trigger correctly or receive full power. Be sure to trigger off of the rising edge of the START pulse. Additional instructions for the various monitoring configurations are detailed in Table 3.

4 Calibration

4.1 Optical Alignment

The following subsections detail the process for optical alignment.

4.1.1 Fiber Coupling Laser Output

Turn the laser on and adjust the x,y, tip, and tilt of the fiber mount. The z-axis can be adjusted by moving the Laser PCB post. For the BLS200, no fine z-axis adjust is available. The Laser PCB light should fill the collimating lens which then couples the light into the fiber. The components are depicted in Fig. 18 below.

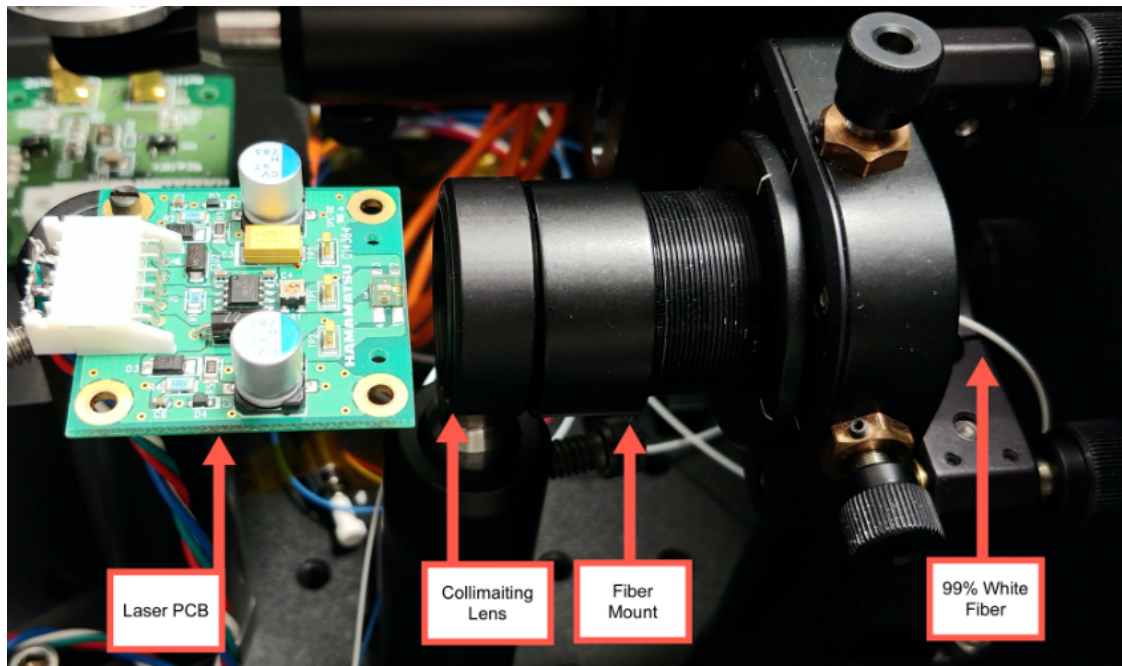


Figure 18: Laser PCB Fiber Coupling

4.1.2 Verifying the Optical Power

To ensure the maximum amount of laser light is coupled into the fiber, connect the 99% tap white fiber to a power meter. **Depending on the PR4 adjustment and subsequent charge voltage available at H5 when the Laser PCB is connected, a power reading between 1mW and 5mW is sufficient.** This is a very sensitive process, so be sure to iteratively adjust the fiber mount in order to maximize the power. Fig. 19 below depicts the software power readout from the Thorlabs integrating sphere.

4.1.3 Aligning the Transmit & Receive Apertures

The transmit aperture needs to be pointing down range and parallel to the ground. Any slight tip or tilt could cause the LiDAR return pulses to bounce at oblique angles which makes detection significantly more difficult. An IR camera can be utilized to verify the transmit aperture alignment at long ranges. If an IR camera is not available, turn

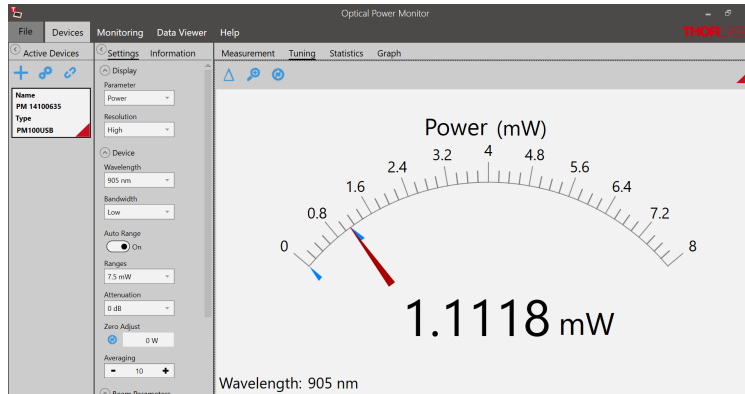


Figure 19: Thorlabs Optical Power Monitor Software Readout. (H5 voltage = 24V)

the laser off, then disconnect the white fiber going to the transmit aperture and the orange fiber going to the receive aperture (to protect the sensor from excess visible laser light). Carefully couple **visible laser light** into the transmit aperture where the white fiber was previously connected. This should allow visible laser light to propagate down range so you can manually align the transmit aperture.

The receive aperture needs to be visually aligned with the transmit aperture. This is a bi-static LiDAR system. If the apertures are not looking in the same direction, it will be difficult to collect enough return light. Ensure the receive aperture is positioned similarly to the receive aperture. Coupling visible light into both apertures and manually aligning the beam spots down range might be the most practical solution.

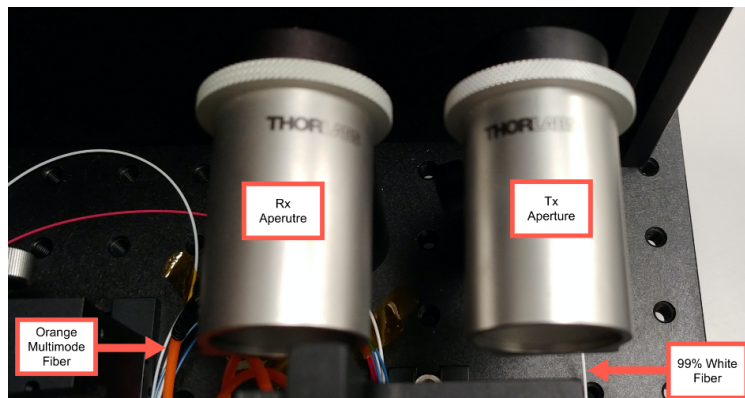


Figure 20: Receive & Transmit Apertures

4.1.4 Aligning the Sensor

First, turn the system power off. Next, use a broadband white light source, for example the flashlight on any smartphone camera, and send this visible light into the receive aperture. The receive aperture will fiber couple this light and focus it down onto the sensor. Finally, manually adjust the sensor stage x, y, and z until the visible white light is tightly focused onto the sensor. When this initial alignment is complete, simply remove the white light source and power the system on. Iteratively adjust the sensor stage x, y, and z until the sensor output is maximized on the oscilloscope. Fig. 21 depicts the Hamamatsu APD sensor beneath the receiving optical axis.

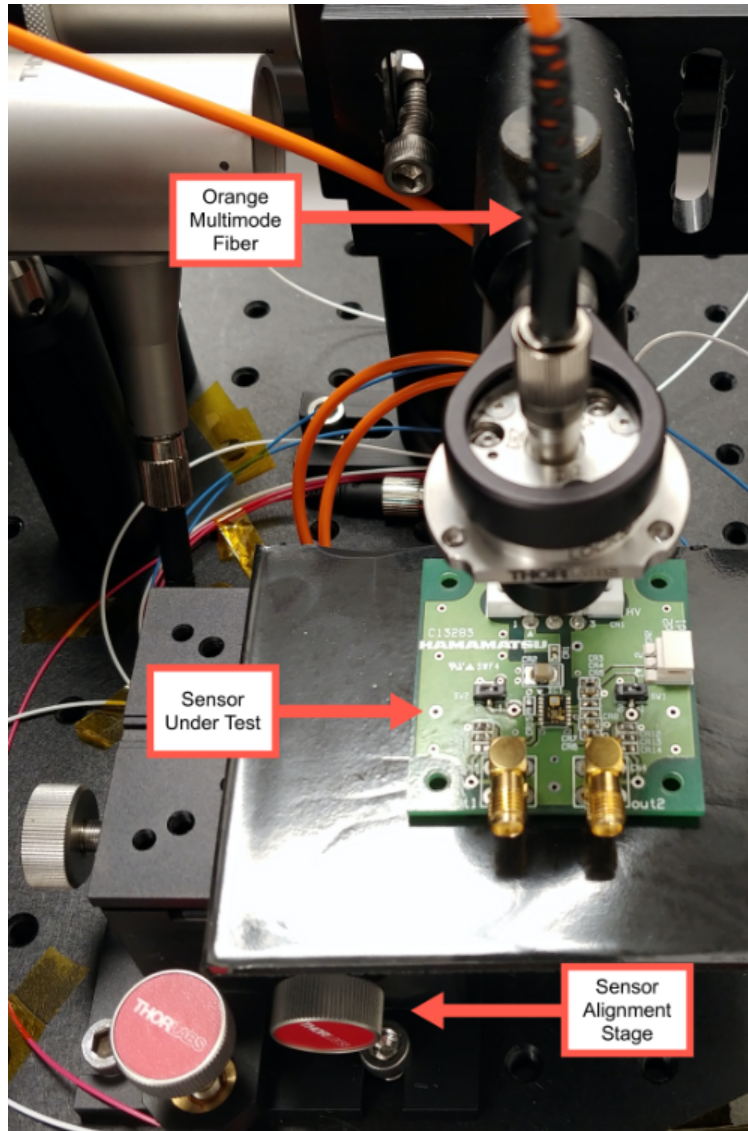


Figure 21: Sensor Alignment

4.2 Electrical Adjustment

The following subsections detail the process for the BLS200 electrical adjustments. Several component names are referenced in this instruction manual. Use the PCB layout in Fig. 22 below to precisely locate the component in question.

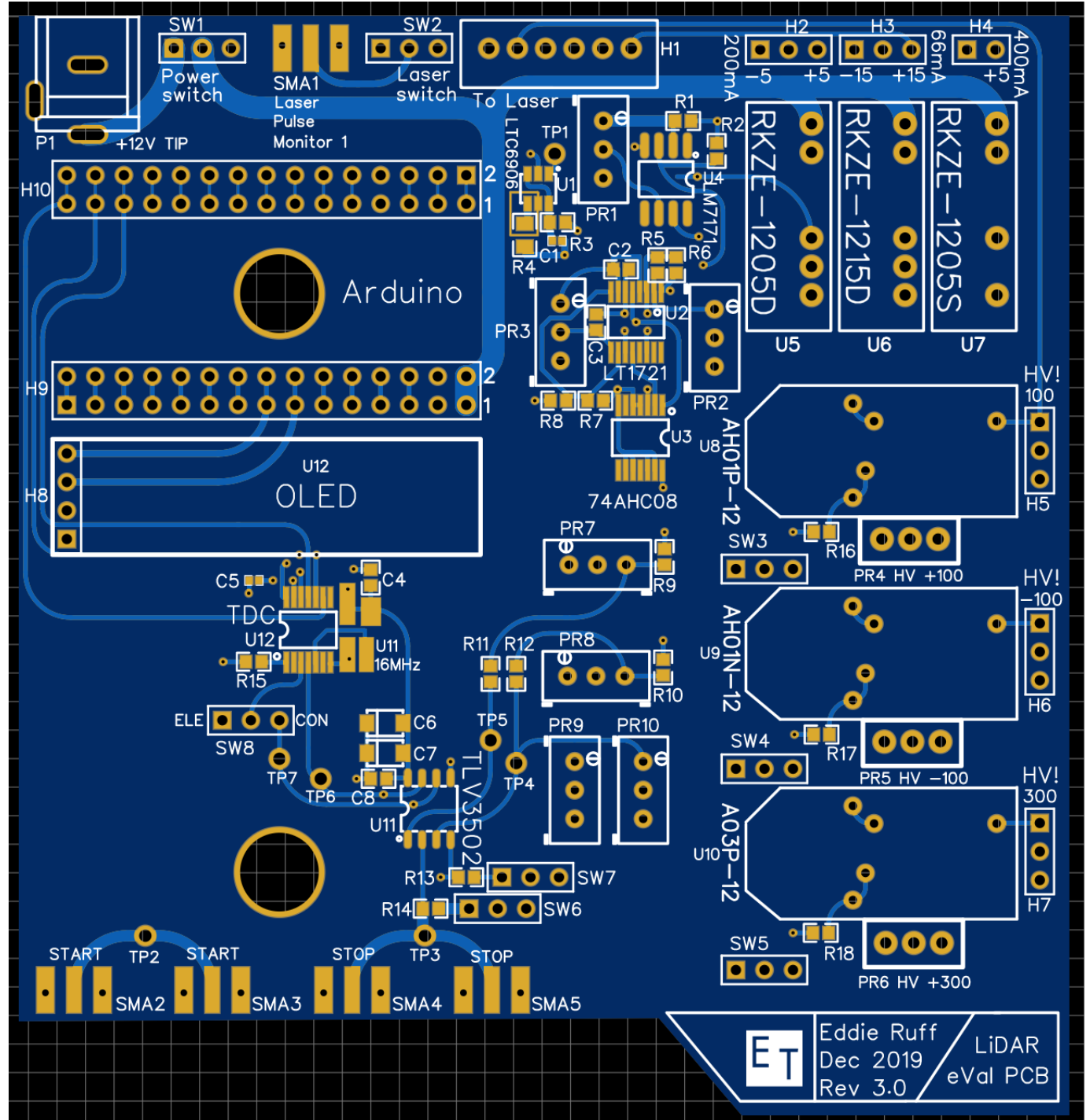


Figure 22: BLS200 LiDAR PCB Rev 3.0.

4.2.1 Pulse Characteristics

Table 2 below lists the expected values for the various electrical pulse waveforms contained in the BLS200. The propagation delay for the STOP pulse is omitted as this varies depending on the sensor under test. Typically, there is some amount of optical bleed from the laser which propagates directly to the sensor. This can be utilized as a first return and compared against the START pulse to determine the total delay not including any fiber lengths (approximately 2.6m).

Location	Test Point	Function	FWHM	Amplitude	Propagation Delay	Termination
LiDAR eVal PCB	SMA1	Laser Pulse	15ns	7V	(earlier) 2ns	1MΩ
LiDAR eVal PCB	SW8 (ELE)	START Pulse	6.2ns	3.3V	(truth) 0ns	1MΩ
Laser PCB	TP1	Laser Pulse	13ns	12.5V	(later) 35ns	1MΩ

Table 2: Electrical Pulse Characteristics for BLS200

4.2.2 Verifying Pulse Clock Signal

The laser PCB requires a Pulse Repetition Frequency (PRF) of 10kHz. An LTC6906 located at U1 generates a 10kHz squarewave signal. The clock shape is not uniform and rises <1V in amplitude. To monitor the squarewave output, simply probe TP1 and terminate the oscilloscope to 1MΩ. Fig. 23 depicts the Laser Trigger Pulse on the top trace (via a connection to SMA1) and the non-uniform, negative edge clock signal on the bottom trace (probing TP1 near U1). Fig. 24 is a zoomed in view of Fig. 23.

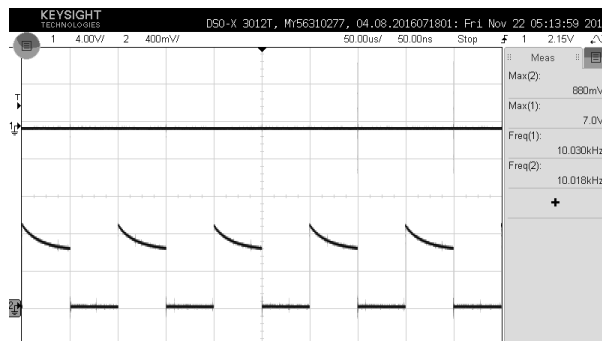


Figure 23: [50μs/Div]. SMA1 Laser Trigger Pulse (top trace) and TP1 near U1 Clock (bottom trace)

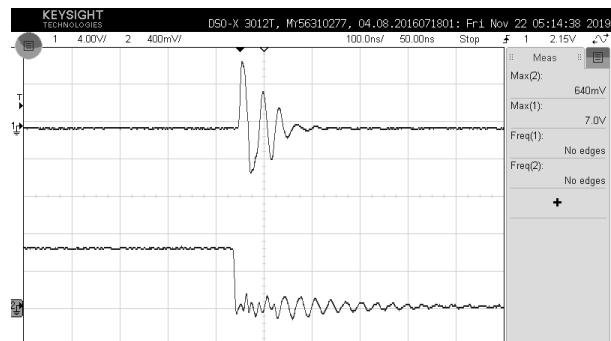


Figure 24: [100ns/Div]. SMA1 Laser Trigger Pulse (top trace) and TP1 near U1 Clock (bottom trace)

4.2.3 Pulse Trigger Adjustment

The 10kHz squarewave PRF is sent to a custom pulse trigger circuit. The falling edge of each squarewave cycle triggers a laser pulse. The pulse trigger circuit has an adjustable FWHM (located at PR3) and input threshold (located at PR2). This pulse can be monitored by probing ELE at SW8. Because the output of the pulse trigger circuit is <5V, the signal is too weak to drive the laser input trigger. So, the pulse is sent to an LM7171 amplification stage located at U4 which increases the amplitude but unfortunately increases the pulse width too. Fig. 25 compares the amplified pulse that is sent to the Laser PCB with the original pulse located at ELE on SW8 which can be sent to the TDC as the electrical START signal. Notice that the signal is only delayed by approximately 2ns. Fig. 26 compares the same amplified pulse that is sent to the Laser PCB with the Laser Diode pulse located at TP1 on the Laser PCB. Notice that the signal is delayed by approximately 35ns.

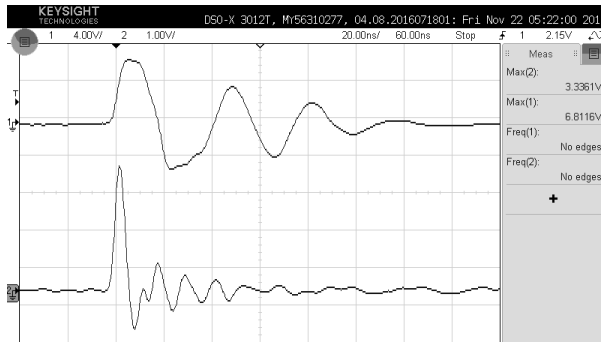


Figure 25: [20ns/Div]. SMA1 Laser Trigger Pulse (top trace) and ELE pulse at SW8 (bottom trace). 2ns Propagation delay.

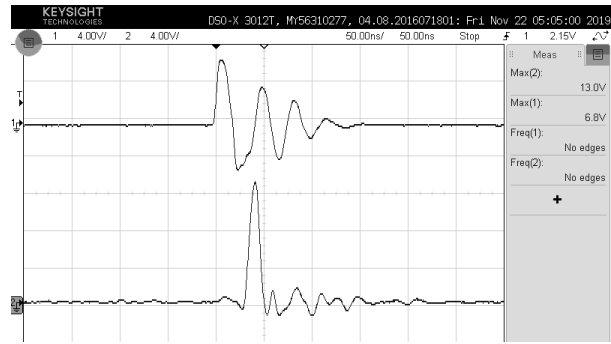


Figure 26: [20ns/Div]. SMA1 Laser Trigger Pulse (top trace) and TP1 Laser Diode Pulse (bottom trace). 35ns Propagation delay.

4.2.4 Verifying Trigger Pulse and START Pulse

To get a better understanding of the total electrical propagation delay. Figure 27 depicts the laser pulse immediately before the Laser Diode (obtained by probing TP1 on the Laser PCB) with the original laser pulse (located at ELE on SW8).

NOTE: The electrical START signal is approximately 35ns earlier than the Laser Diode Pulse.

The electrical START pulse is what feeds the TDC for ToF readout on the OLED. The TDC inputs are NOT 50Ω terminated. So, the <3.3V peak voltage should be manually adjusted via PR3 when terminated to 1MΩ on the oscilloscope. A peak voltage >3.3V could damage the input of the TDC located at U12.

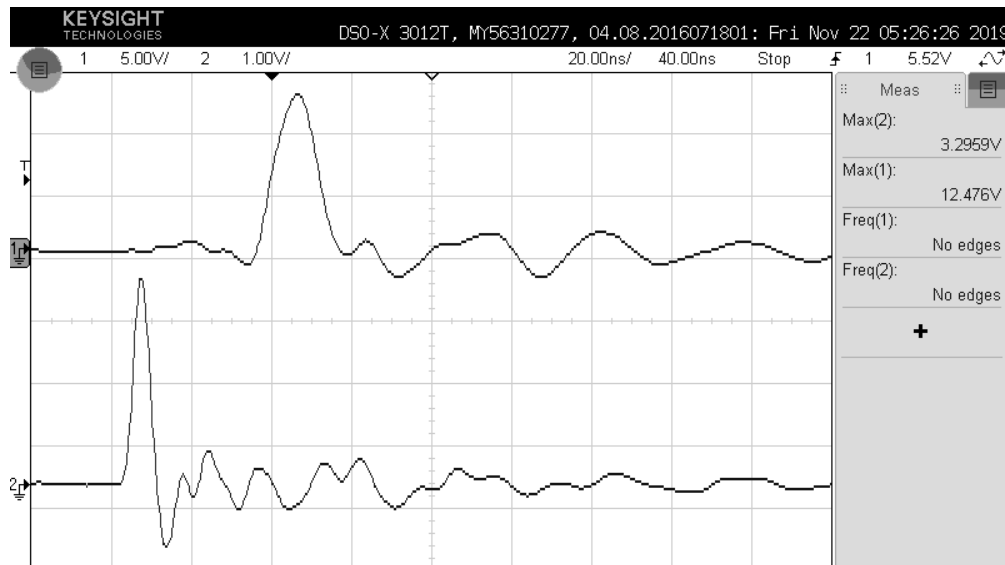


Figure 27: [20ns/Div]. TP1 Laser Diode Pulse (top trace) and ELE pulse at SW8 (bottom trace). 35ns Propagation delay.

4.2.5 Return Pulse Conditioning

The raw output from the sensor under test is usually a very low voltage. Several sensors include their own Trans-Impedance Amplifier (TIA) to improve the amplitude of the detected signal. The user can send these signals to the TDC circuit (located at U12) which will provide the ToF information. But first, the sensor signals must be sent

to a TLV3502 comparator (U11) which generates pulses that satisfy the TDC input requirements (0V to 3.3V peak >6ns FWHM). There are four adjustment trimmers associated with U11. Trimmers PR7 and PR8 control the voltage reference for the comparison for the STOP and START pulse respectively. This voltage reference can be monitored via TP4 and TP5. The user can also adjust the hysteresis of the comparator in order to avoid false triggers. The hysteresis can be adjusted via PR9 and PR10. Table 3 below depicts the required configuration for monitoring the various start and stop configurations.

Function	Probe Location	How to Enable
Electrical START (Conditioned)	ELE near SW8	SW8 red slider in rightmost position. U11 is not utilized.
Optical START (Conditioned)	CON @ SW8 or TP7	SW8 red slider in leftmost position. Adjust PR8, PR10, and SW7 accordingly.
Optical STOP (Conditioned)	TP6	Connect raw signal to SMA4 or SMA5. Adjust PR7, PR9, and SW6 accordingly.
Optical START (Raw)	SMA2, SMA3, or TP2	Nothing to enable. Only conditioned signals are sent to the OLED.
Optical STOP (Raw)	SMA3, SMA4, or TP3	Nothing to enable. Only conditioned signals are sent to the OLED.

Table 3: Pulse Configurations for OLED display

5 Troubleshooting

5.1 Why is there no laser output?

Ensure the LiDAR eVal PCB is correctly powered and both SW1 and SW2 are correctly positioned. An IR indicator card can be utilized to check the laser output immediately before or after the laser collimating lens. If there is still no laser output, ensure the correct voltages and pulse signal is reaching the laser PCB. Verify the Clock signal at TP1 near U1, then the pulse at ELE near SW8, finally check SMA1.

5.2 Why do the Start and Stop Monitor outputs not work?

Please ensure the jumper connectors are correctly configured for U2 and U3 monitoring. Also verify the termination of the scope, use a 1MΩ termination if the TDC is utilized. Otherwise, a 50Ω termination is typical for most sensors.

5.3 Why is the Time of Flight (ToF) readout incorrect?

The ToF converter circuitry does not do any signal averaging. For this reason, false triggers, temporary loss of signal, jitter, and noise will affect the ToF readout. For example, single APDs with little to no bandpass filtering will exhibit several false triggers and returns which will confuse the ToF readout. On the other hand, a MPPC with a correlated array of APDs will perform much better with the current ToF circuitry.

The ToF circuitry can also be tested with electrical pulses to verify performance. Ensure the pulse width and peak voltage meet the requirements for the TDC circuit or damage could occur.

5.4 Why is there no return pulse?

First, ensure the system is powered on and the laser is triggering properly. You can use an IR indicator card immediately after the laser collimating lens before the fiber coupling. If you see a bright green spot (the IR card fluorescing) then the laser is operational. Next, ensure the fiber coupling is correctly aligned. You can use a

Thorlabs integrating sphere to verify the laser output. Simply connect the 99% (white) or 1% (red) fiber tips to the power meter. If the power meter responds appropriately, then the laser light is fiber coupled. Next, ensure the white fiber is connected to the transmit aperture.

The pulse is now propagating down range towards a target. A portion of the return pulse should be collected by the receive aperture. This is then fiber coupled and focused onto the sensor under test. Assuming the sensor is correctly powered and aligned, a return pulse should now be detected unless the sensor is not sensitive enough for the given amount of return light.

5.5 How do I change the sensor?

First, turn the system power off. Next, remove the existing sensor under test and any accompanying PCB specific to that sensor. Then, mount the new sensor beneath the receiver lens. Ensure the required voltages are connected to the sensor. Some sensors require high voltage for Geiger mode operation, or even negative voltages. Failure to apply the correct voltages could result in sensor damage. With the sensor connected, slowly adjust PR7 and PR8 from a fully CW (OFF) position to a CCW (ON) position in order to supply the correct breakdown voltage for the sensor under test. Once the new sensor is mounted, roughly aligned, and correctly powered, perform the final alignment with the sensor adjustment stage.

5.6 How do I align the sensor?

First, turn the system power off. Next, use a broadband white light source, for example the flashlight on any smartphone camera, and send this visible light into the receive aperture. The receive aperture will fiber couple this light and focus it down onto the sensor. Finally, manually adjust the sensor stage x, y, and z until the visible white light is tightly focused onto the sensor. When this initial alignment is complete, simply remove the white light source and power the system on. Iteratively adjust the sensor stage x, y, and z until the sensor output is maximized on the oscilloscope.

5.7 How do I connect a single-ended sensor?

For sensors with a single-ended output, simply connect the output to U6 or U7. This will maintain the single-ended operation, however the RF transformer has a limited bandwidth and suppresses the DC component of the output. If the pulse polarity is incorrect, switch the U6 or U7 connection.

5.8 How do I connect a differential sensor?

To preserve the signal integrity and further prevent noise, many optical sensors provide a differential output after Trans Impedance Amplification (TIA). The differential outputs can be connected to U6 and U7 of the LiDAR eVal PCB. Note, the RF transformer has a limited bandwidth and suppresses the DC component of the output.

5.9 I cannot obtain a return pulse.

First, ensure that the laser is aligned correctly and transmitting pulses. Then, verify that the receive aperture is correctly aligned and the return light is incident upon the sensor under test. Optically aligning the sensor is a very delicate process and should be done iteratively to verify that the maximum return signal is obtained. Finally, ensure that the sensor is positioned and powered correctly. An improperly biased sensor could result in no signal. Similarly, improper output termination and/or flipped terminal polarity could cause no signal.

5.10 I think I broke something.

Please contact the authors of this instruction manual via email. Send a photo of the suspected damage and a complete timeline of the steps which caused the damage.

6 Warranty

The BLS200 is a custom product intended for internal use by the user. ET reserves the right to revise the information in this document without notice. ET provides this documentation without warranty of any kind, either implied or expressed, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. ET reserves the right to make changes or improvements in the product(s) and/or the services described in this documentation at any time. ET takes no responsibility for damaged components either by shipping, mis-handling, mis-use or under normal operation.

All brands, products, service, and company names not belonging to Exciting Technology LLC mentioned in this document may be the trademarks or registered trademarks of their respective companies.