TSI 3010 CPC: Replacing initial Sony SLD201V-3 laser diode with Roithner LaserTechnik QL78J6S-A

Contents

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Overview

Original Laser Diode Discontinued

Per https://gml.noaa.gov/aero/docs/newsletter/NEWSLETTER_5.pdf in the "Obsolete Equipment" section

> *For the CPCs, the critical failure is that the laser diode (Sony SLD201V-3) is no longer being produced. In the past, we would simply repair collaborator TSI 3010s and 3760 CPCs, including laser replacement. Unfortunately, we can't do that anymore as we can no longer get the replacement laser.*

Considerable research has found QL78J6S-A, a suitable diode with two manufacturers. Roithner Lasertechnik was selected because of availability and international relationship with the US.

QL78J6S-A Specifications

These TO-18 lasers have the same pinout, but are 5.6mm instead of 9mm. The specifications include 775 to 795 nm wavelength, 50 mW continuous power, 2 to 2.8 V operating Voltage, 75 to 100 mA operating current, 25 to 40 mA threshold current, and a feedback photodiode. ***These new diodes are much more efficient and will be destroyed if you use the original TSI electrical board.***

Acknowledgements

I really want to thank NOAA for letting me build on Jim Wendell's fantastic "Replacing and tuning the laser on a TSI 3010 or TSI 3760 CPC" guide. I have plagiarized pictures and text as a starting point for this procedure. Jim has retired from NOAA.

I also want to thank Maynard Havlicek from TSI for his invaluable help.

Warnings:

1. This procedure is specific to the TSI labelled laser board. Other versions are out there, so check before you start ordering parts.
2. This is not a simple process. You will need someone with knowledge of the TSI 3010 basics with a decent amount of electrical and technical skill. This is a DIY project, but a challenging one. Plan 2 days for the first time you do it.
3. I (patrick richardson) take no responsibility for damage to your equipment. This procedure documents what I did to make our TSI 3010 return to full functionality. Your mileage may vary.
4. I would appreciate any feedback or recommended modifications to the procedure. Please send them to richardsonpj@appstate.edu.
5. **LASER WARNING:**
   - ***780 nm laser light is in the IR region: you can barely see the light but the intensity is sufficient to permanently damage your eyes.***

- ***Don't look directly into the laser.***

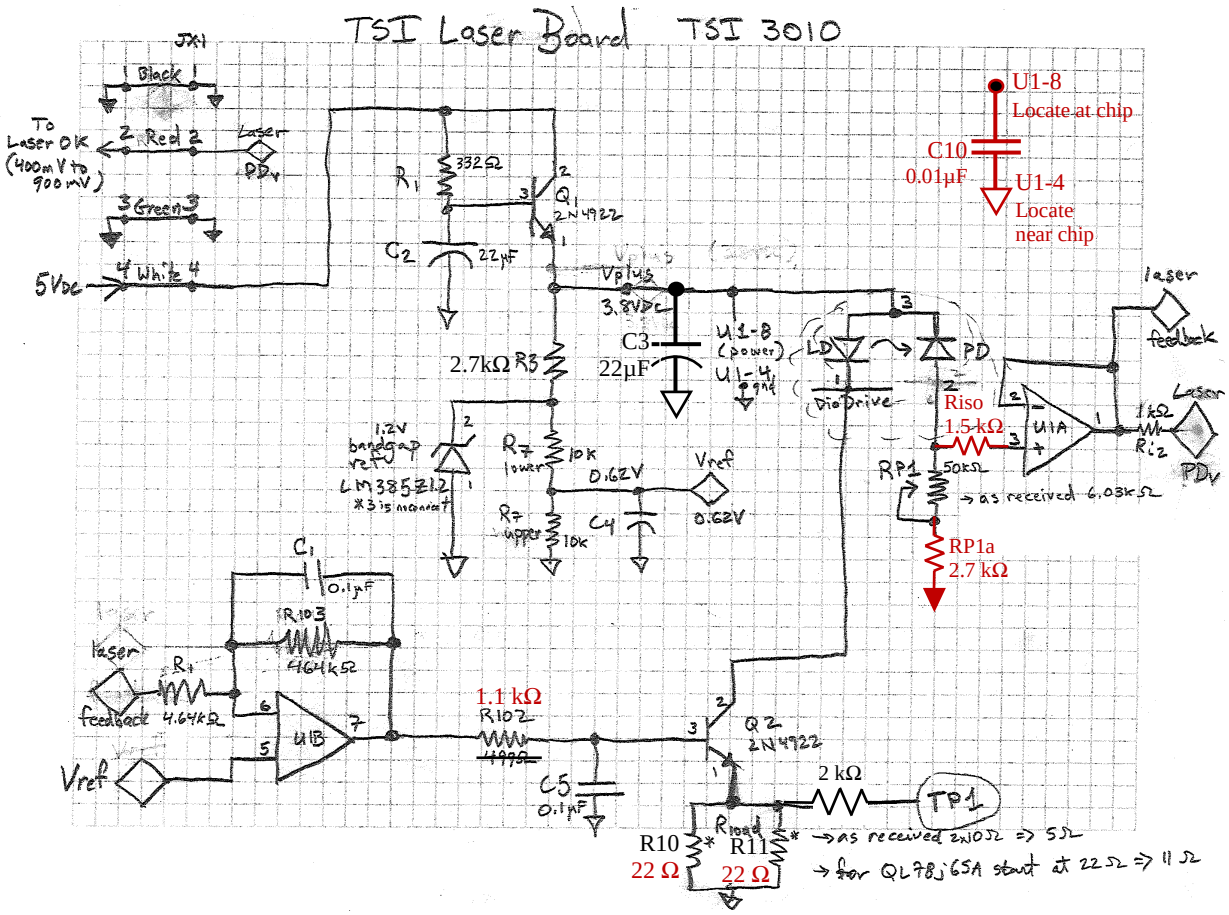
5.6 mm Laser Conversion on a TSI 3010

Design Change

In order to use the new smaller and more efficient laser diode, modifications to the PWB are required or the laser diode is destroyed. The modifications in this procedure have been operating in our AppalAir CPC.

Reference Figure 1, TSI Laser Board Changes, on page 3. Value changes are marked in red while new components and their values are entirely in red.

Figure 1. TSI Laser Board Changes



Preparation

Tools required:

- Philips head screw driver
- 0.050, 5/64", and 7/64" hex keys
- Solder station with solder sucker or solder wick
- Oscilloscope (2 channel min) and probes
- Electronics working vise
- Precision tweezers
- Painter's tape
- Kim wipes, single ply toilet paper, or similar
- ESD mat (use normal ESD precautions working with the PWBs)
- Loktite 242 (medium duty thread locker)
- Four extension wires with 0.1" headers- plug on one side and receptacle on the other. An Arduino header works perfectly.
- 9/32" Socket
- Small press
- 1/16" (1.59 mm) diameter rod minimum 5/8" (15mm) long- a piece of welding rod works
- ***ONLY if removing the diode from the conversion ring *** 1/8" (3.18 mm) diameter rod minimum 7/16" (10mm) long

Parts Required

- QL78J6S-A 780nm laser diode (I suggest purchasing 3 when/if you damage one). You can find them in the US (expensive and long lead time) or get them direct from Roithner Lasertechnik at roithner-laser.com (from Austria but 1/3 the cost and probably in stock). There are other suppliers and manufacturers. Specifications are in section QL78J6S-A Specifications on page 2.
- Two 22 Ω, 1%, 1/4W, PTH resistors
- 1.1 kΩ, 1/8 W or higher PTH (pin through hole) resistor
- 2.7 kΩ, 1/8 W or higher PTH resistor
- 1.5 kΩ, 1/8 W or higher PTH resistor0.01 µF PTH 10V or higher capacitor
- 5.6mm to 9mm diode holder conversion ring (purchase off the shelf if you can find it). It will look like that in Appendix A: 5.6mm to 9mm Diode Conversion Ring Drawing on page 20. You can use that design if you can't find one.

Suggested Accessories

- Four extension wires with 0.1" headers- plug on one side and receptacle on the other. An Arduino header works perfect as shown in Figure 8 "Example Extension Cable" on page 10.

Equipment Overview

Figure 2, Top View of Optics Block, shows the green PWB (Printed Wire Board) on the left, the main optics block (black) in the center, and the detector (silver) on right. These are attached to the optics block with machine screws.

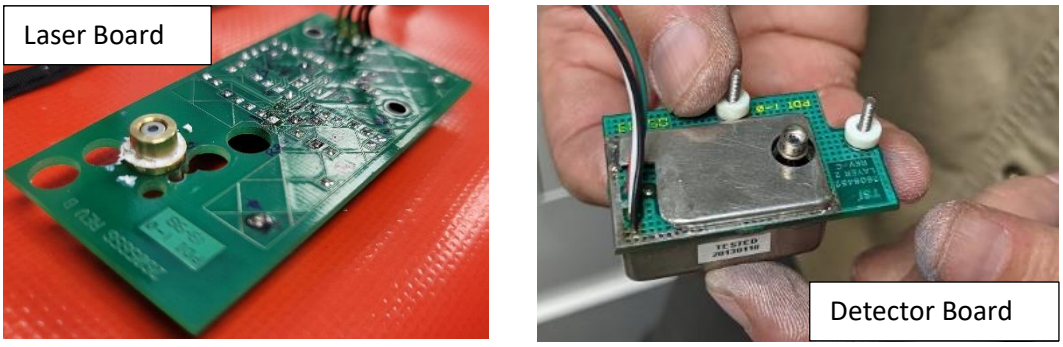
Figure 2. Top View of Optics Block and PWBs

Procedure

Disassembly

1. Highly suggest draining the butanol reservoir. This is not required, but is recommended in case the CPC is tipped to the side.
2. Label the clear hoses connecting to the optics block for reassembly
3. Disconnect the hoses from the optics block
4. Remove the CPC optics block from the condenser by removing the two Allen screws on top and from the back panel by removing the two Philips screws. The top hex screws may need to be pulled out after the rear screws are removed using precision tweezers
5. Disconnect the power/signal cables from the main circuit board to the laser and detector PWBs.
6. Making sure to note the position of the spacers, remove the laser and the detector PWBs (reference Figure 3 on page 6) from the optics block by removing the two small screws that secure each of them to the block.

Figure 3. Laser and Detector PWBs



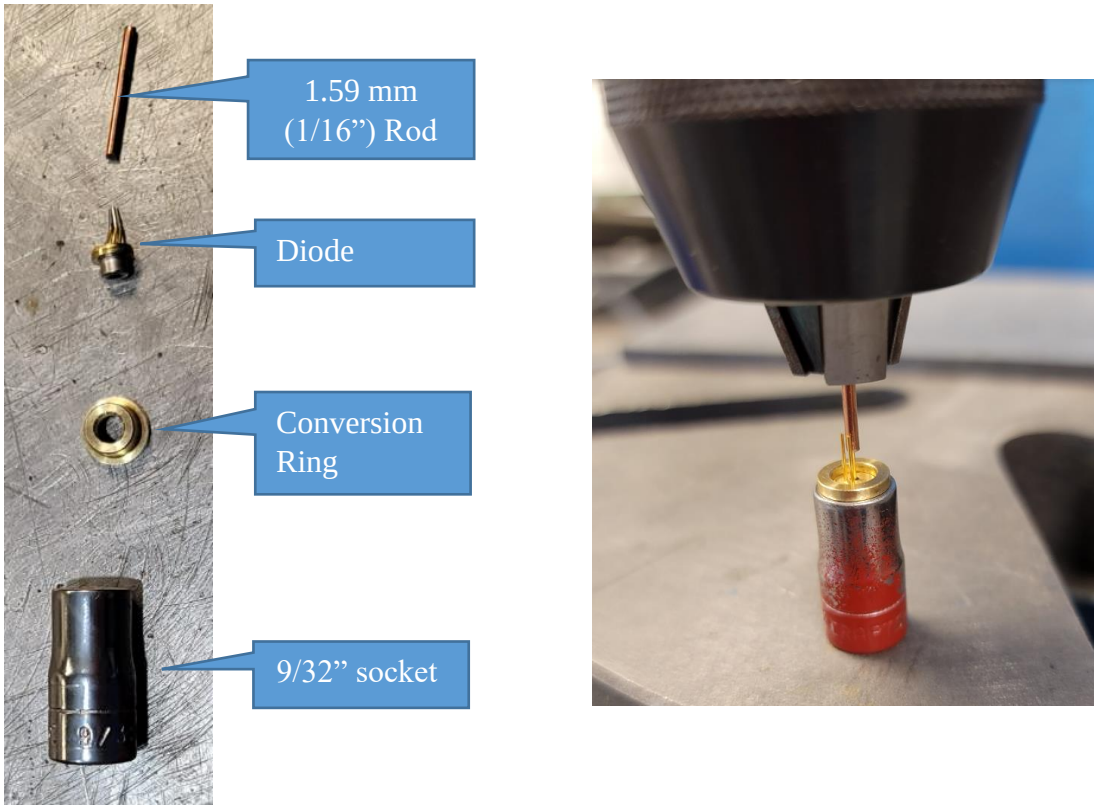
7. Cover the optics block holes with painter's tape to protect them.
8. Set the optics block and the detector board assembly aside for now.

Laser Diode Holder Conversion Ring Insertion

Reference Figure 4 for images of the process.

6. Align the parts in the order shown
7. Using a press if at all possible, place the rod in the center of the diode's three pin and gently push the diode a tiny bit (less than 1 mm)
8. Check that the diode is going into the Conversion Ring evenly. If not, move the pin to different areas of the diode surface to keep it level
9. The laser diode must fit snugly and be pushed all the way in. DO NOT deform the metal can by pushing too hard

Figure 4. Laser Diode Insertion



Rework

Reference Component Side Rework Figure 5 "Component Side Rework" on page 8 and Figure 6 "Solder Side Rework" on page 8 for the following steps

1. Secure the board component side up in the electronics rework vice. The laser will be facing down.
2. Remove laser diode from the board.
3. Cut trace from U1 pin 3 to the intersection of the trace between photodiode and potentiometer. DO NOT cut the trace from the potentiometer to the photodiode.

Figure 5. Component Side Rework

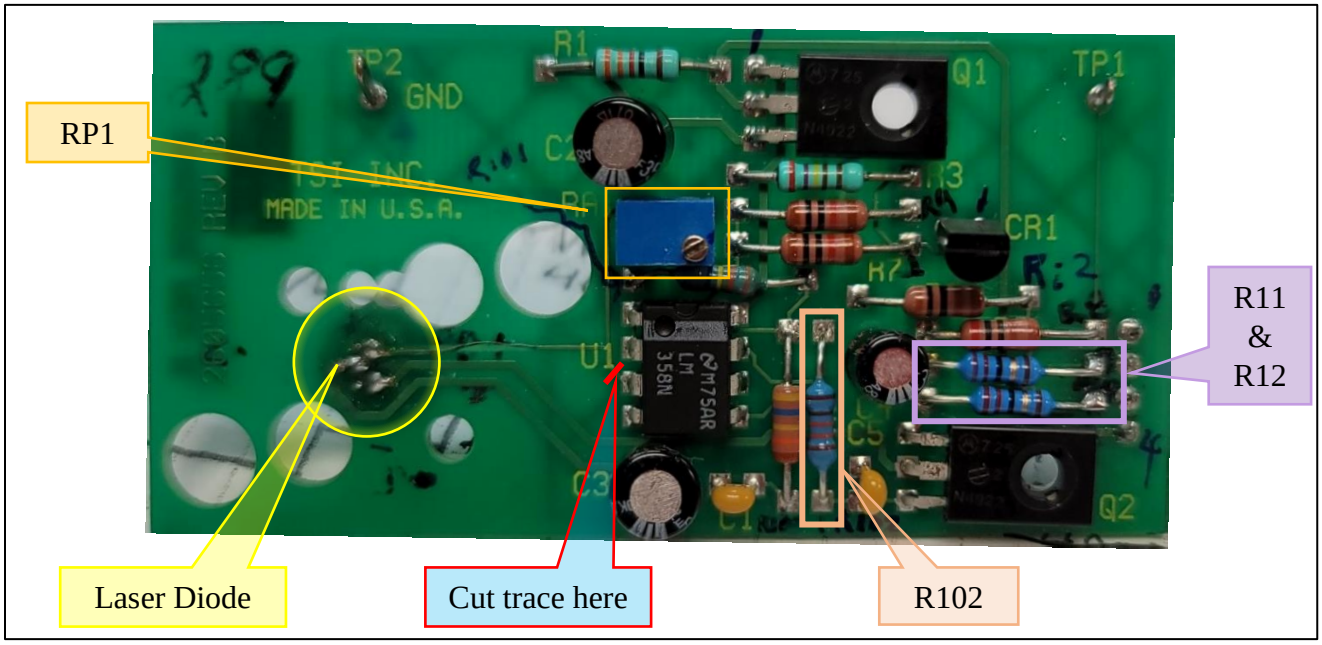
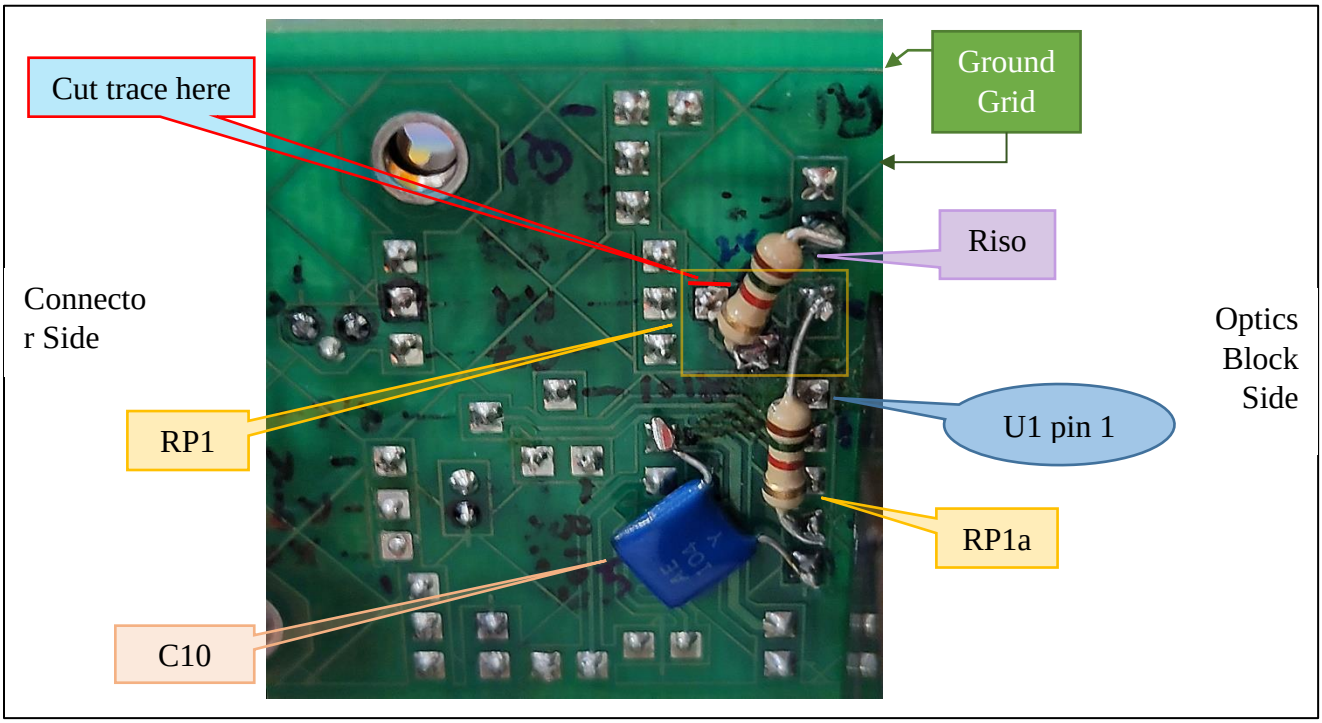
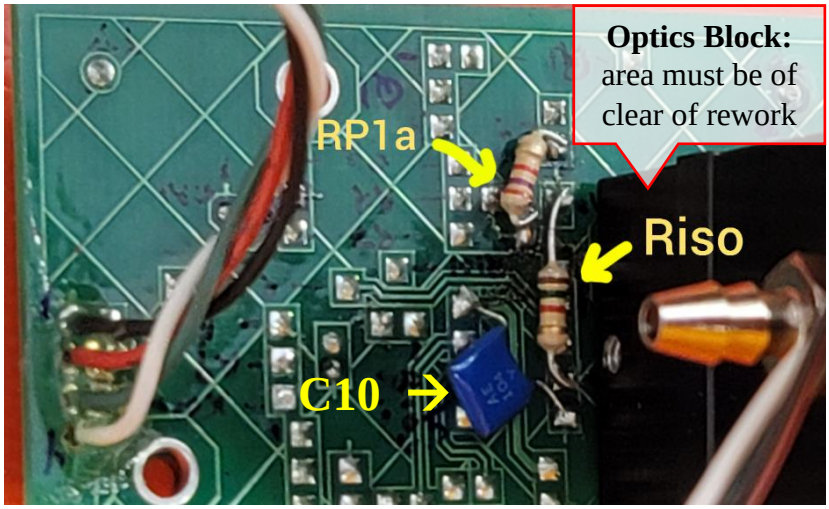


Figure 6. Solder Side Rework



4. Secure the board solder side up in the electronics rework vice
5. Replace R11 (10 Ω) and R12 (10 Ω) with the two 22 Ω resistors
6. Replace R102 (499 Ω) with the 1.1 kΩ resistor.
7. Cut the trace from RP1 to the ground grid on the solder side. It is a VERY short trace.
8. Press the laser diode assembly into the TO-18 holes. Once you have the diode holder and laser diode FULLY pushed against the PWB, solder it in place. The holder must be flush with the surface of the PWB and the laser snugly seated in the holder. If it has any play, the later alignment will be unstable.
9. For the next three steps, it is important to have the components placed so they do not interfere with the Optics Block once it is reattached. Components should be located towards the connector side of the soldering pads-- reference Figure 7 on page 9.
    a. Add 2.7 kΩ RP1a from the RP1 pin 2 & 3 common connection (that used to connect to ground) to the ground connection on C3.
    b. Add 1.5 kΩ Riso from U1 pin 3 to the photodiode and potentiometer trace accessible on RP1
    c. Add 0.01 µF C10 from U1 pin 4 to U1 pin 8.

Figure 7. Rework Optics Block Clearance



10. Check the resistance between PD (the new laser's photodiode, pin 3) and ground. Set RP1 so the impedance is near or at maximum (around 52 kΩ). This sets the current to minimum for the later LD (laser diode) adjustment.

Laser Diode Output Verification

WARNING:

780 nm laser light is in the IR region: you can barely see the light but the intensity is sufficient to permanently damage your eyes.

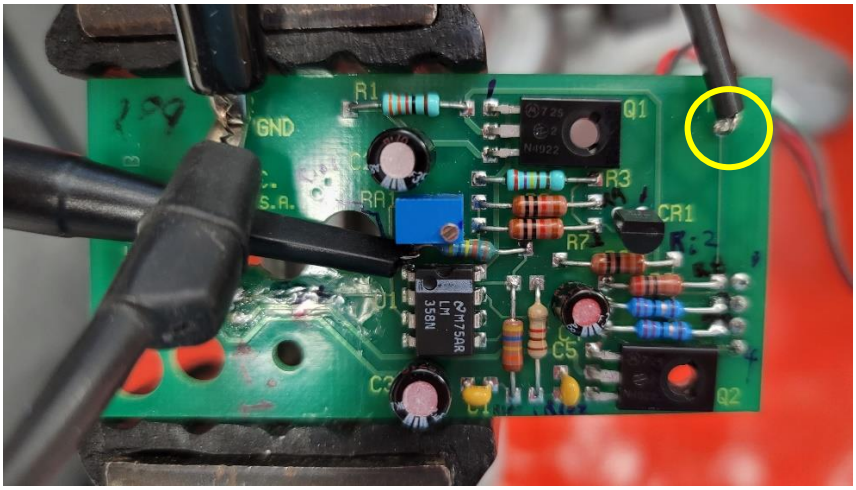
Don't look directly into the laser.

The following steps are easier if you make an extension cable as shown in Figure 8 below.

Figure 8. Example Extension Cable

10. Connect the Laser Board to the CPC using the extension cable. Attach a scope probe to TP1 (yellow circle in Figure 9). There is a ground post as shown.

Figure 9. Laser Board Test and Initial Adjustment



11. Turn on the CPC while monitoring the Voltage at TP1. The Voltage is measured at the

emitter of Q2 and is used to measure the current through the LD. The current is equal to TP1's Voltage divided by 11 Ω (parallel combination of R11 and R12).

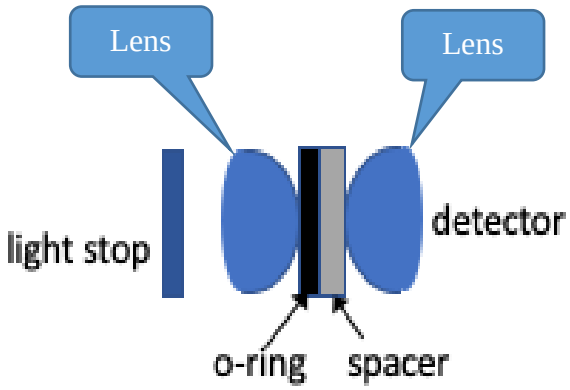
12. Adjust RP1 so that TP1 reads 440 mV to have 40 mA flowing through the LD. (Note: 40 mA is the upper threshold Voltage for the QL78J6S).
13. Verify that there is a laser output using a sheet of paper at the laser output. If there is no laser, check all of the modifications for shorts, opens, or any other potential issues.

Optional Lens Cleaning (per NOAA instructions)

Note: while doing laser replacement, may consider also cleaning the optics. *note: directly copied from NOAA's "Replacing and tuning the laser on a TSI 3010 or TSI 3760 CPC" guide

Optics block - has two lenses. There's a spacer and an o-ring between the lenses. They (the lenses) can be removed by pushing with cotton swab. DON'T push on light stop. The lenses are the same, so it doesn't matter which one goes where, but orientation with respect to each other is important. The lenses aren't special - they can be cleaned with lint-free paper and ethanol.

Figure 10. Schematic of lenses in Optics Block

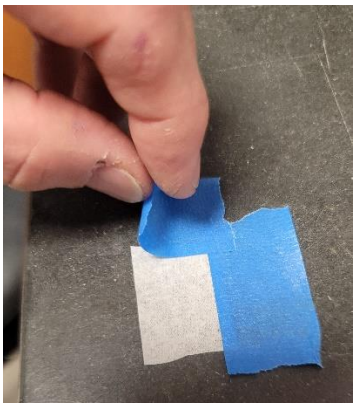


Assembly:

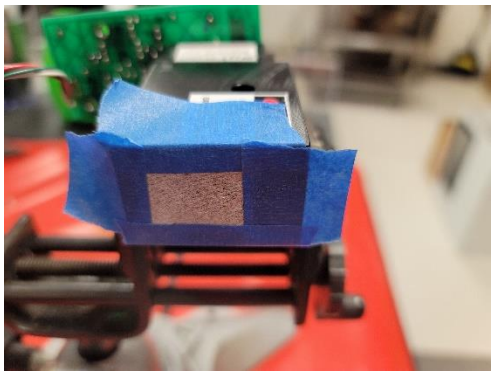
1. Put light stop in the channels/grooves in optics block
2. Insert first lens. Use tube with slight vacuum on it to set lens. Inserting with flatter edge first so vacuum goes on more curved side.
3. Check that light stop hasn't moved and lens appears to be flattish.
4. Insert o-ring. Will need to work down so it sits on first lens
5. Insert spacer ring
6. Insert second lens, more curved side down.
7. Screw down cover that holds lenses in place.

Optics Alignment Preparation

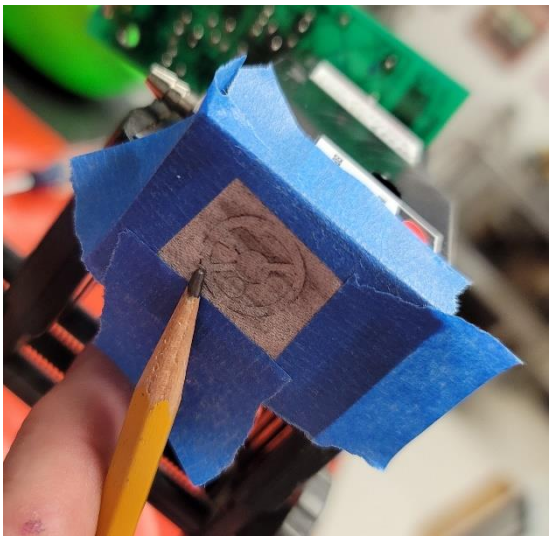
1. Power off the CPC
2. Attach the Laser Board to the Optics Block using the two Philips head screws noting the following
   - You will NOT want to loosen these screws again as it will throw off the alignment. I used Loktite 242 to reduce the chance of movement.
   - The Laser Board's TP1 and TP3 need to be facing up, i.e. towards the laser warning label, not the cone.
3. Build a display screen over the detector hole. The following steps are one option.
4. Cut a 2.5 cm square piece of Kimwipe and set it flat on the table. Cover all four sides with tape leaving a 1.5 to 2.0 cm exposed area of Kimwipe for a screen.



5. Pull the screen up and affix it over the center of the optics block detector hole.



6. Using a standard pencil, make a rubbing to exactly outline the detector opening



7. Place painter's tape over the laser board's exposed solder side circuitry facing the optics block to avoid shorting traces during adjustment.
8. Mount the assembly in the electronics vice and connect the laser board to the CPC if not already done. Set it so you can see both sides of the optics block.

X-Y Optics Alignment

Please examine Figure 11, Laser Adjustment / Tuning Block, on page 14.

There are three adjustments, X, Y, and Z. All of the adjustments are made using 0.050" hex keys.

Each of the adjustments are made by loosening one of the screw pairs and tightening the other. It is important to do these in small steps no greater than ¼ of a turn at a time. Having two hex keys are very handy as you can twist each one small amounts in opposite directions until they lock. Both screws must be tight for the optics to be secured.

Figure 11. Laser Adjustment / Tuning Block

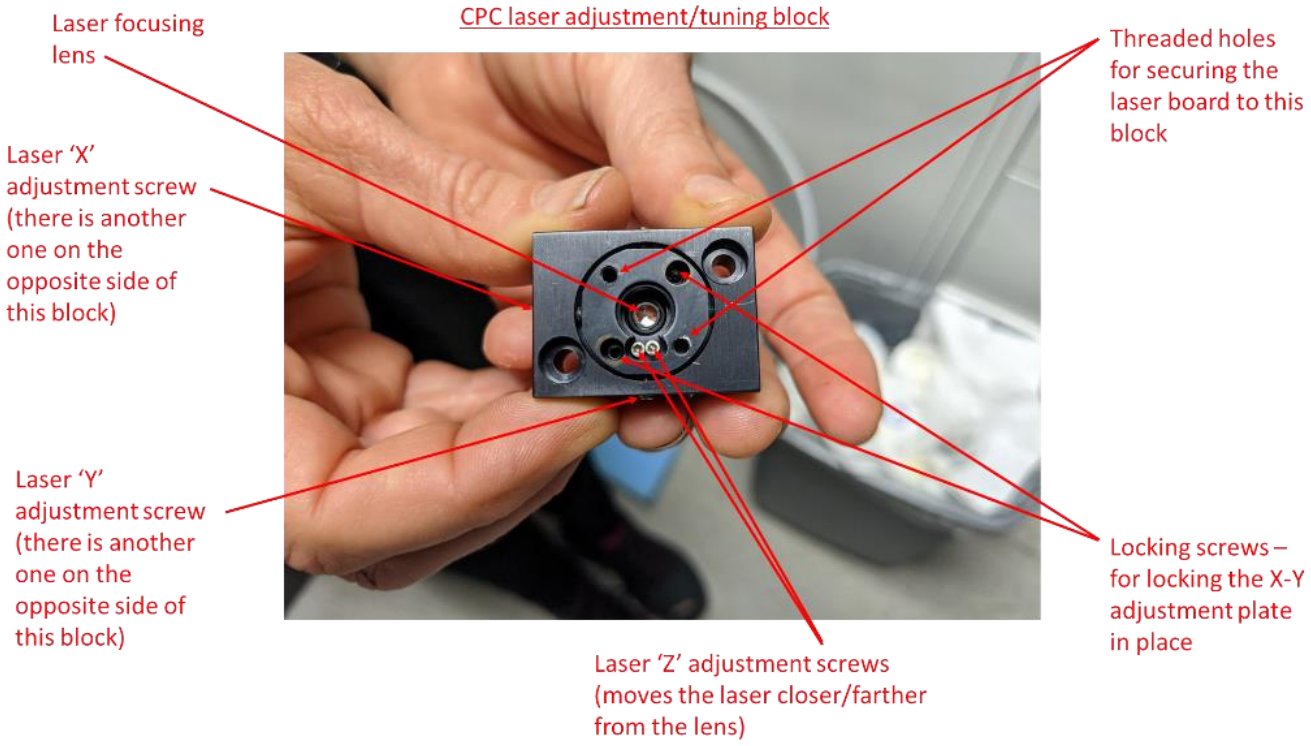
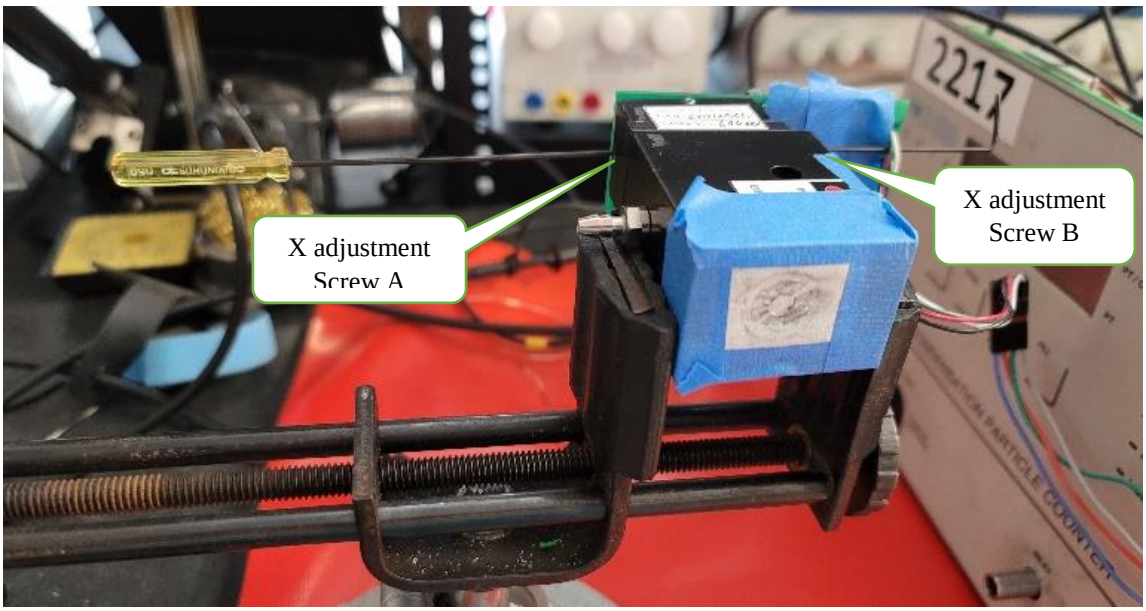
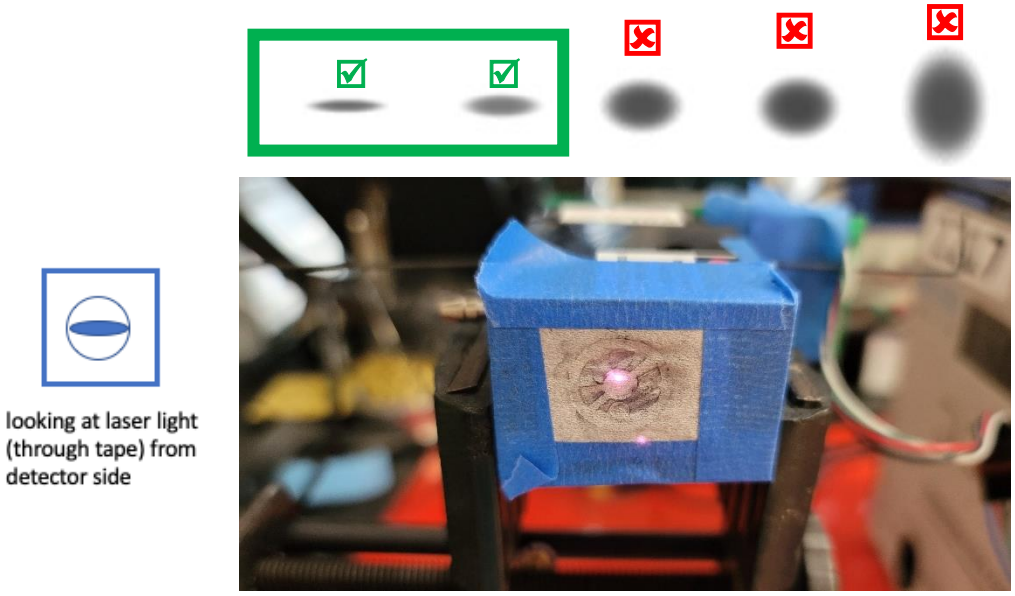


Figure 12. Optics Block Setup with X direction hex keys in place



1. Referencing Laser Adjustment / Tuning Block in Figure 11 on page 14, loosen the two 5/64" X-Y locking screws 1/8 turn. Loosen more if you must for adjustment, but the less free play the better.
2. Turn on the CPC
3. Using the X and Y adjustment screws on the sides and top of the Optics Block, adjust the laser beam up (or down) and left (or right) to obtain a beam pattern as shown in Figure 13 below. 'X' and 'Y' are less sensitive than 'Z' so you can get pretty good adjustment for them visually. You want to see the whole beam (red spot) slightly above center.

Figure 13. Beam Pattern



4. Once you have the beam centered in the X direction, tighten both 'X' screws. You may need to make fine adjustments until you get it spot on.
5. Now lower 'Y' so that the beam is completely blocked by the light trap (beam stop). If you go too far, the beam will begin to appear below the beam stop. You want them beam blocked as much as possible. Tighten both 'Y' screws.
6. Tighten the two 5/64" hex X-Y locking screws for the adjustment plate firmly.
7. Verify the signal is still blocked and power off the CPC.

Z Optics Alignment

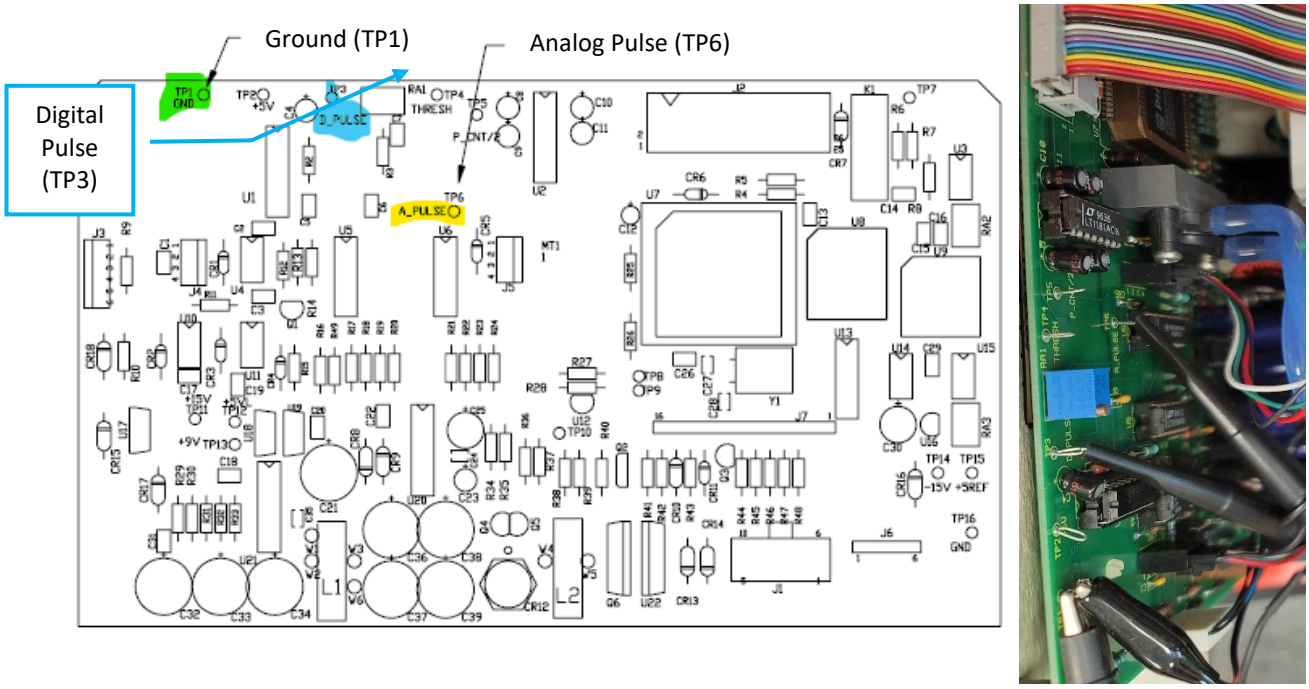
Reference Figure 11, Laser Adjustment / Tuning Block, on page 14 for the adjustment screw locations

1. Remove the screen from the detector diode opening on the Optics Block.
2. Attach the Detector Board to the Optics Block using the same spacers that were originally in

the unit you noted in step 6 in the Disassembly section on page 5.

3. Attach oscilloscope probes to TP6 and TP3 as shown in Figure 14 and described in "Viewing Analog Pulses" of TSI's Model 3010 Condensation Particle Counter Instruction Manual's Chapter 6.

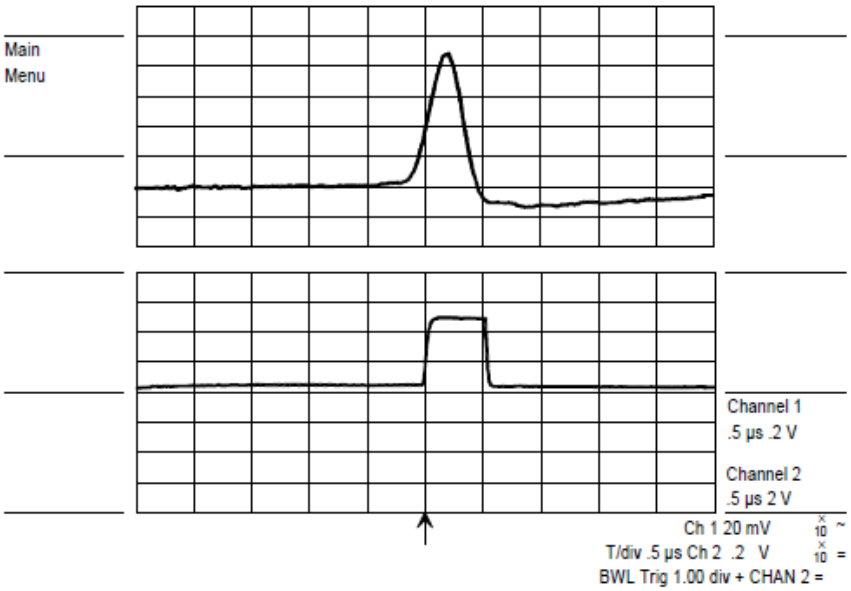
Figure 14. Z-Axis Adjustment Test Points



1. Remove all tape from the Optics Block
2. Restore the Optics Block assembly back into the CPC, attach the hoses, fill the butanol, and start the vacuum pump.
3. A good starting point is to set the oscilloscope for
   - Analog pulse channel to AC coupled 200 mV/div, 500 nS/div, trig on 200mV rising edge (Note- the analog pulse rides on a 7.5V DC offset)
   - Digital pulse channel to DC coupled 1V/div
4. The Model 3010's manual states

> "The minimum <analog> pulse amplitude is about 500 millivolts and the pulse width is about 0.5 microseconds (Figure 6-2). The pulse amplitude may range as high as 1 volt. The electrical noise level is about 10 millivolts, giving an overall signal-to-noise ratio of better than 20:1."

Figure 15. Pulse from TSI Manual Figure 6-2



5. Power on the CPC
6. Adjust the Z axis until you reach the maximum signal amplitude. WARNING: the signal amplitude varies widely! The goal will be to keep the highest signal amplitude from being clipped and the lowest above 500 mV. This will probably not be possible, but use your scope triggering skills to achieve the best possible balance.
   - Figure 16 shows a good quality signal
   - Figure 17 shows the variation of the signal under normal conditions
   - Figure 18 shows a clipped signal (avoid)
7. If the typical signal amplitude is below 500 mV, one of the two following problems are the likely sources.
   a) **The Detector Board is too far out from the Optics Block.** This depends on the type of laser diode holder you are using— the one we found made the diode move backwards about 0.6mm, so we removed one spacer. If the final beam pattern in the X-Y Optics Alignment section was not a very tight pattern, this is the most likely option.
   b) **The laser diode power is too low.** If the above step does not get you the output needed, adjust RP1 so that you get sufficient gain, ensuring it is below 75 mA. Reference the Laser Diode Output Verification section on page 10 for how to measure the diode current.
8. If clipping is occurring regularly, lower the LD amplitude using RP1 until clipping is avoided.

Figure 16. Good Quality Signal

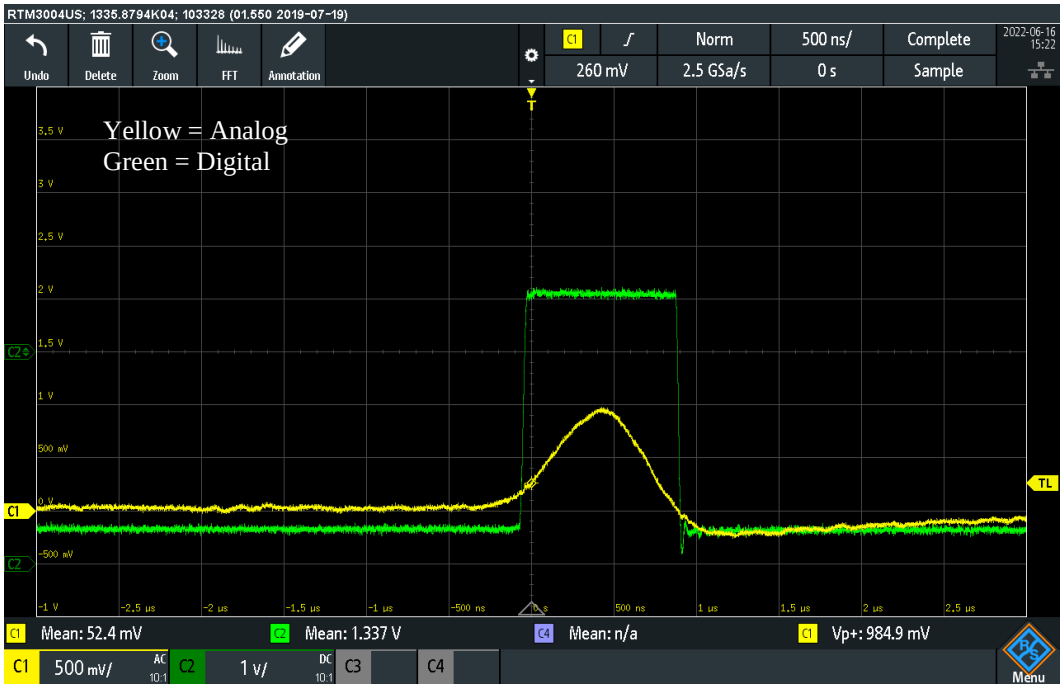


Figure 17. High Persistence Scope Capture Showing Signal Variation

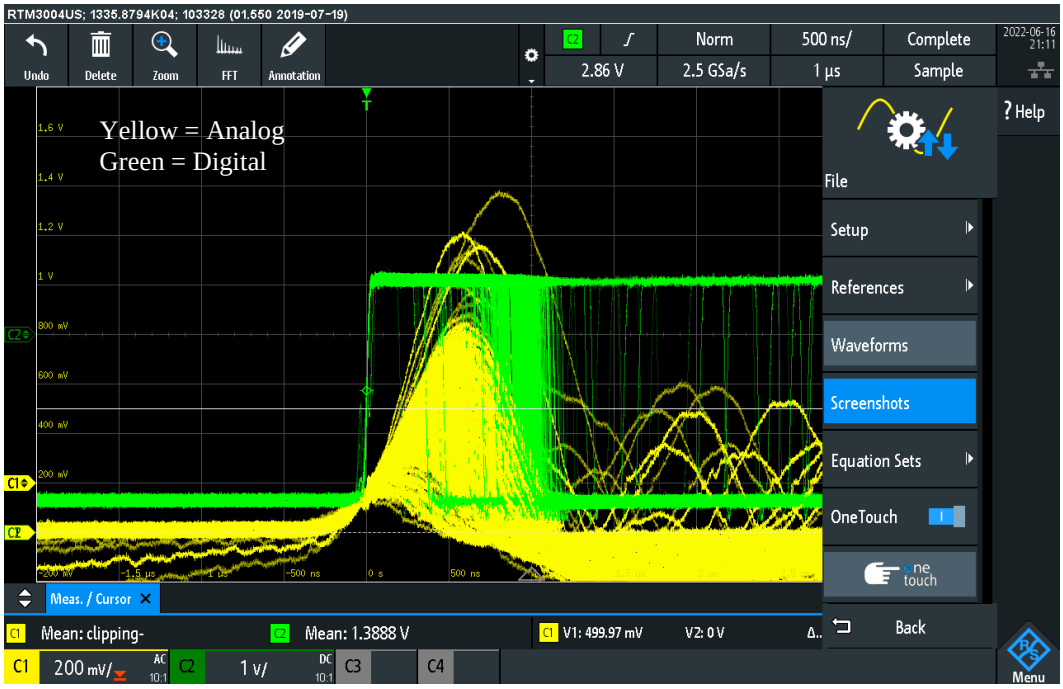
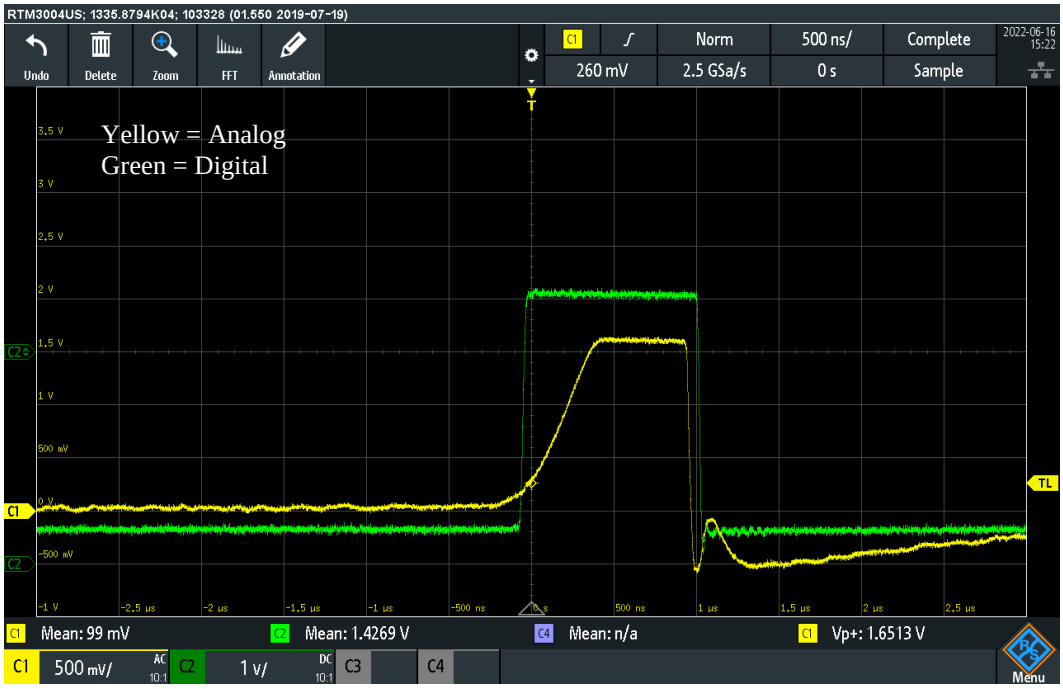


Figure 18. Example of Clipped Analog Signal (note analog at 500 mV/div)



9. Remove probes and put the cover back on

Appendix A: 5.6mm to 9mm Diode Conversion Ring Drawing