State of Florida

Department of Transportation

OPERATIONS MANUAL FOR MOBILE RETROREFLECTIVITY UNITS

FDOT Office
State Materials Office

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PAVEMENT MATERIALS SYSTEMS SECTION

The mission of the Pavement Material Systems Section is to monitor and report on the condition, structural adequacy and performance of Florida's roadway system and to provide technical expertise for safe and long-lasting pavement systems.

Our vision is to be acknowledged by our customers and partners as achievers of excellence in the evaluation and performance-prediction of pavement systems.

To learn more about our people, functions and services, we invite you to visit us at http://materials.dot.state.fl.us/smo/pavement/pavementhome.htm

EXECUTIVE SUMMARY

One of the functions of the Non-Destructive Testing Unit, a unit of the State Materials Office in Gainesville, Florida, is to evaluate the in-situ performance of pavement striping on Florida's roadways so that District Maintenance Engineers can more effectively plan re-striping strategies. This handbook has been developed as a reference for personnel responsible for or interested in the processes involved in the principles of retroreflectivity and equipment used to measure it. The handbook provides detailed explanation of the Mobile Retroreflectometer Unit (MRU) along with information vital to its operation and is intended to serve as reference for those using such equipment in the State of Florida. Covered in this manual are the concepts and physics involved with retroreflectivity, setup and calibration of the MRU, and MRU operational procedures. Finally, this manual explains the tasks required to perform proper data analysis and describes methods to archive important information for later use.

INTRODUCTION

One of the functions of the Non-Destructive Testing (NDT) program is to characterize the in-situ performance of pavement striping along Florida's roadways to effectively plan restriping strategies. The basis for such characterization is the retroreflectivity value (R_L). The retroreflectivity value is a measure of the fraction of emitted light reflected back to its source per unit area and can be directly correlated to how well drivers see pavement striping with their headlights on in low lighting conditions or darkness.

Obtaining retroreflectivity values for pavement striping is important for this reason: In situations where there is very little lighting along roadways, the visibility of pavement markings is known to play a major role in the amount of nighttime accidents. Nighttime visibility of markings is typically provided by the ability of pavement markings to reflect headlamp light back to the driver (retroreflectance). Since providing street lighting generally requires high installation, operating, and maintenance costs, lighting is typically used only in specific areas. Thus, the nighttime visibility of pavement markings is primarily dependent on their retroreflectivity.

The retroreflectance of pavement markings generally decreases over time for a variety of reasons: abrasion by traffic, sun and heat exposure, application methods, material type and chemicals spilled on the road surface. Thus in order to ensure safety, a prescriptive specification has typically been employed for marking maintenance. Under this specification, the type of marking material and the method of application are controlled. The marking is then replaced after a predefined interval based on previous wear data. This tends to sacrifice either cost or safety since the markings are either replaced while still providing adequate service for drivers or after the retroreflectance has deteriorated to a point that the markings are no longer visible at night. For a performance specification, continuous assessment over the life of the markings is necessary to ensure visibility and reduce unnecessary costs of remarking.

In 1993, the United States Congress directed the U.S. Department of Transportation to include a minimum level of retroreflectivity for signs and pavement markings in the Manual of Uniform Traffic Control Devices (MUTCD). Subsequently, the Federal Highway Administration (FHWA) initiated a program to develop instruments to measure the retroreflectance of signs and markings. Due to their speed and ease of operation, the mobile pavement marking van was developed in partnership with the private sector through the Small Business Innovative Research Program (SBIR) and has been successfully commercialized. Because of the millions of dollars that the State of Florida spends each year on pavement markings, it was determined that pavement markings need to be considered as a manageable asset. While there are less expensive handheld retroreflectometers currently on the market, only a mobile based platform is capable of efficiently collecting the vast amounts of data needed to monitor pavement marking performance.

Mobile based retroreflectometers are used for estimating the retroreflectivity value of striping. Retroreflection can be non-destructively induced and measured using various commercially available devices. These devices are designed based on using a light source and optical lenses

and filters as measurement sensors. The units can be configured to measure edge lines, skip lines, and centerlines along roadways and can be mounted on either side of the vehicle.

FDOT's Road Vista Mobile Retroreflectometer Units (MRUs) are a light measurement device that consists of a light source capable of illuminating longitudinal pavement markings at a set distance in a manner that imitate actual driver and vehicle headlights in both position and geometry (i.e. angle of entrance and angle of reflection). A retroreflectivity scan is generated by shining a single point light source (usually a laser) at a rotating mirror out at a specified distance from the source. The rotating mirror causes the laser to move in a sweeping motion about 1.2 meters in length, 10 meters in front of the unit on to the pavement stripe. Optical sensors are used to convert the amount of reflected source light to a proportional voltage at approximately 200 different evenly spaced intervals along a 1.2 meter scan width. A retroreflectivity value is obtained based on the peak data point values averaged along the generated scanned area after filtering out any signal noise produce by the asphalt or concrete pavement. Over 20 of these scans are performed every second along the stripe width. The retroreflectivity values from all these scans are averaged out over a user defined interval and an average retroreflectivity value is obtained over that interval. The MRU relies on the law of averages as the basis for collecting accurate data. In this methodology, a single reading is unimportant to the overall result as the retroreflectivity value for each interval is typically based on hundreds or thousands of individual scans. Figure 1 shows a photographic illustration of one commercially available retroreflectometer, which is in use at the Florida Department of Transportation State Materials Research Park.

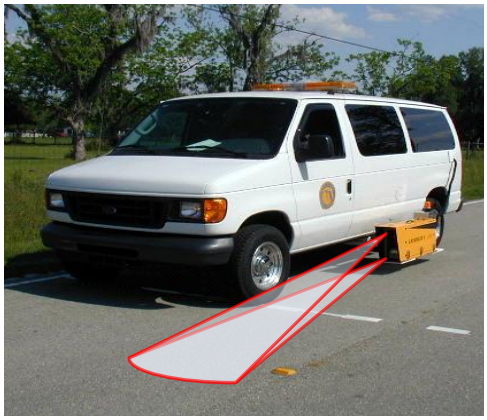


Figure 1 - Mobile Retroreflectivity Unit

DERIVING THE UNITS OF RETROREFLECTIVITY

Retroreflectance measurements are typically given in terms of millicandelas per meter squared per lux. This unit is essentially a fraction of emitted light reflected back into the direction of the light source. The significance of this unit may be found by studying the definitions of various terms associated with light such as luminous intensity, luminous flux, illuminance and luminance. Luminous intensity is the intensity of light emanating from a source in a given direction (Figure 2). The magnitude of this vector is measured in terms of candles (cd), where 1 cd is the intensity of 1 candle. As an example, a typical 100W light bulb emits an average of 110 cd.

Figure 2 - Luminous Intensity

The luminous flux is the sum of the luminous intensity of a source in all directions (Figure 3). Thus if the intensity is isotropic (emits evenly in all directions) then one can multiply by 4π to arrive at the luminous flux. Luminous flux is typically given in terms of lumens (or lm). As an example, the same 100W incandescent light bulb emits around 1400 lm.

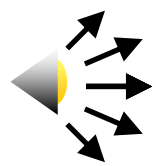


Figure 3 - Luminous Flux

An increased value for the luminous intensity for a light source may not correspond to a bright image. This may be due to the area over which the luminous intensity is spread. Luminance is the luminous intensity of an emitting object divided by the plan area of the emitting object. It is typically expressed in terms of cd/m^2.

Illuminance is the metric that is usually used to describe a lighting level on a particular surface such as a table or a wall. Illuminance is the luminous flux received on a plane per unit area of that plane. While the units are typically given in lux (lm/m^2), the plane may be oriented in many different angles, thus orientation of the plane should be given. It is important to note that this may not be based on what is seen by the observer on the plane as some surfaces (such as a table) may have a coating, or color which does not reflect its illumination.

Thus retroreflectance is the luminance (or brightness) of an object as detected by a sensor divided by the illuminance of the object by a light source.

Retroreflectance = Luminance/Illuminance = $\left(\frac{cd}{m^2}\right)\cdot lux^{-1} = \left(\frac{cd}{m^2}\right)\cdot\left(\frac{m^2}{lm}\right) = \frac{cd}{lm}$. (eq. 1)

The areas cancel since the area illuminated is the same as the area used to calculate the brightness. Since lumens in this calculation refer to the total luminous flux of the light source and cd is the luminous intensity of an area of interest, retroreflectivity is a measure of the fraction of the reflected light source intensity as received by the sensor.

LASERLUX MOUNTING PROCEDURE

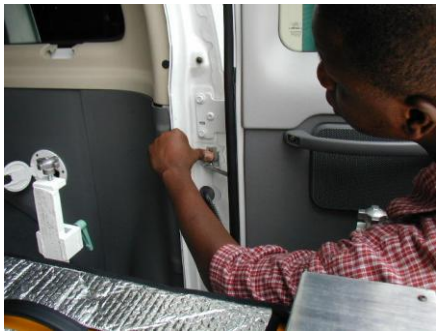
Instructions for physically mounting FDOTs Road Vista Laserlux units onto the van are provided in this section. Calibration instructions are provided in the following section. Properly mounting the unit onto the van is critical to calibrate the unit. Also, a unit improperly mounted can result in serious damage to the unit itself, the van, other traffic, and could also result in bodily harm.

The following are the mounting procedures:

1. Inflate tires to their operational pressure (80 psi rear and 80 psi front when cold, make adjustment based on manufacture recommendation). This is important not only to preserve the tire tread, but also to insure that the onboard DMI stays correctly calibrated.

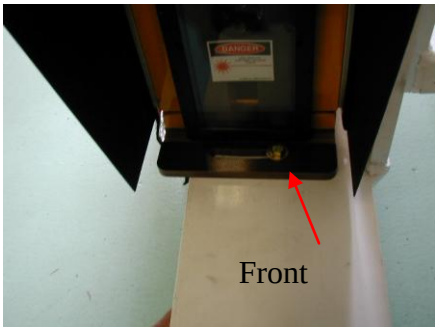
2. Remove L brackets from the equipment bag with their respective lock pins and insert them on the side of the vehicle where the Laserlux is to be installed.

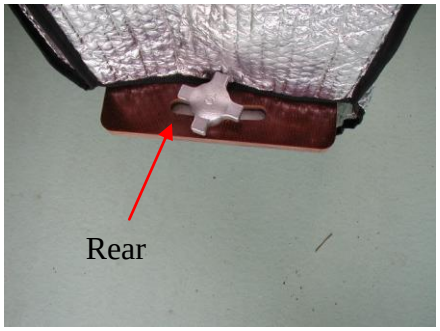
3. At the rear of the vehicle, remove the set pin from the storage tray to allow the tray to slide out to the rear of the vehicle. Note that a clip may be disengaged to allow the door to open wider if necessary.



4. Unscrew the white mounting bracket from the mounting tray and place the mounting bracket on the L brackets.

5. Unscrew the Laserlux from the storage tray. Handles are placed on the unit to allow for an easier grip while lifting. Place it on the white mounting bracket with the Lexan window facing towards the front of the vehicle. Screw the Laserlux onto the mounting bracket on the side of the vehicle. Be sure to use a 3/8 inch bolt with washer to secure the front of the Laserlux so there is no interference with the laser. The bolt with the knob can be used to secure the rear of the Laserlux. The front of the Laserlux usually gets pushed away from the vehicle as far as the slot will allow and the back is adjusted as close to the vehicle as the slot will allow which allows the driver to angle the Laserlux slightly to maintain operation of the vehicle in the center of the driving lane. Additional adjustments may need to be made depending on the position of the vehicle in driving lane.





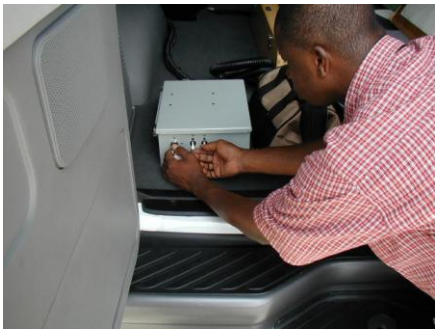
Note: If the heat shield blanket is to be used, ensure that it is folded up on the side closest to the vehicle and the other side is fitted around the bottom of the mounting bracket. Use the nylon straps provided in the equipment bag to strap the heat shield in place. Secure

any excess strapping. If the unit does not require a heat shield, simply place the unit onto its mounting position and secure with mounting screws.

6. Using the keys attached to the vehicle keychain, open the side access port and fit the wires provided through the port. In the side access port door, open a smaller door for a better fit for the wires coming through and attach them to the rear of the Laserlux.

a. For ease of connection, make sure the silver stripe on the large black female connector is positioned up and that there is no water in any of the connectors. Complete the connections to the internal video monitor, strobe light and thermoelectric-cooler at this time too, if being used. Make sure the side port is closed and locked when finished.

7. At the junction box in the rear of the vehicle, turn the key switch to the on position and additional toggle switches as well. Unless already done, return the storage tray to its locked position with its set pin in.



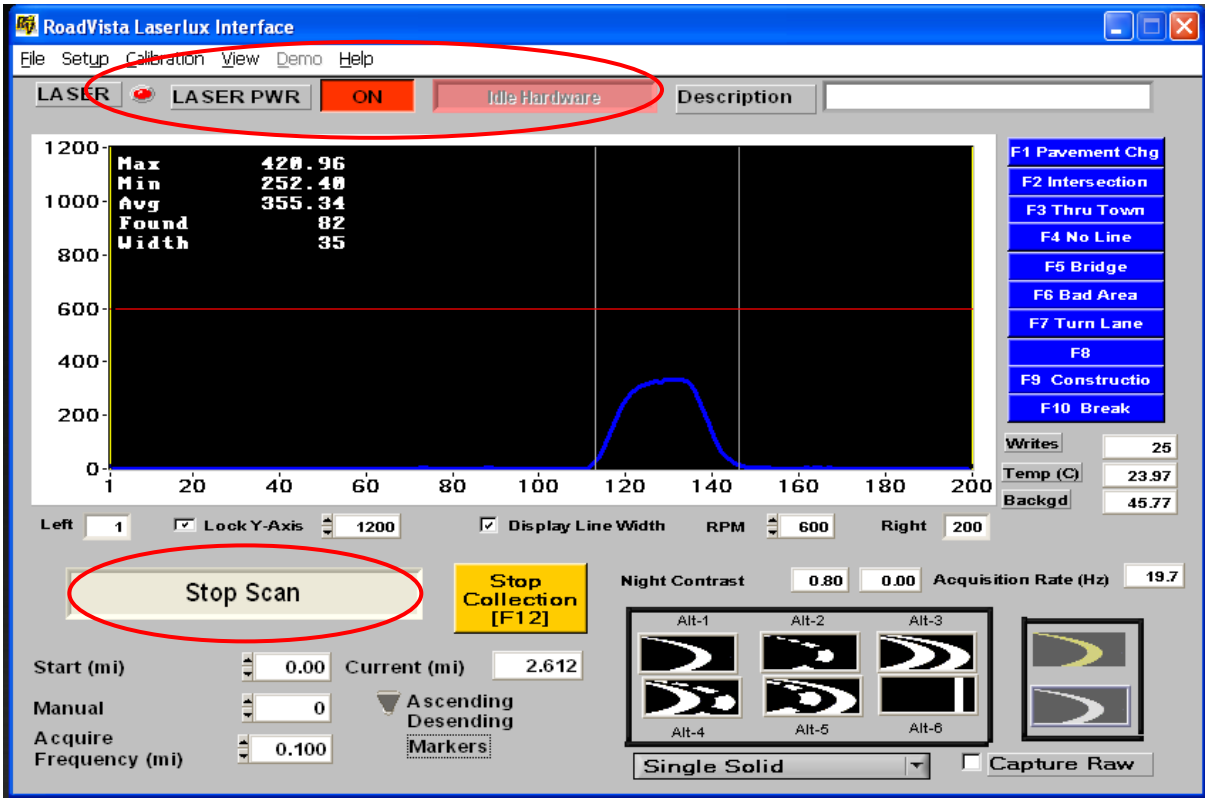
8. Clean the Lexan panel on the Laserlux using standard window cleaning solution. This is critical as dirt, bugs, or fingerprints can block the outgoing laser light and returning light, thus interfering with the measurement.

EQUIPMENT CALIBRATION PROCEDURES

GENERAL CALIBRATION PROCEDURE (VERSION V2.2.9.1)

Procedures for calibrating FDOTs Gamma Scientific Laserlux units are defined in this section. The Mobile Retroreflectometer Unit (MRU) is a very sensitive optical measuring device and therefore, proper calibration is critical. Unlike other roadway testing equipment which may only require calibration verification or recalibration of their respective unit every month or even less frequently, the MRU requires calibration every time it is used. Also, anytime the unit is transferred from one side of the vehicle to the other or even moved to its resting position inside the vehicle, it must be recalibrated prior to the next use. The following are the steps required to calibrate the MRU:

1. Power up the laptop and double-click to start the Road Vista Laserlux program. Click the Green, *Initialize Hardware* button first (changing it Red and to *Idle Hardware*) followed by the *Start Scan* button. By doing this you are starting up the laser and controlling the temperature of the electronics and optical devices. A warm-up time is critical for these components to function properly. Allow the equipment to run for at least 15 minutes prior to attempting a calibration. During this warm up period is a good time to replenish the fuel in the vehicle and drive around to loosen the suspension.



2. With the unit electronics still running, move the van onto a level surface of which there is also at least 10 meters (32'9.75") of the same level surface in front of the vehicle. This 10

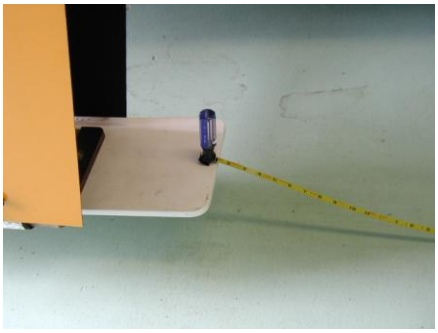
meter length directly in front of the vehicle must also be free from obstructions (speed bumps, rocks, other vehicles, etc.).

3. The bottom of the mounting bracket should be adjusted to a height of 5.21 inches from the ground. A height adjustment stand (stand measuring 5.21 inches) can be used to set the height of the Laserlux unit. This is accomplished by placing the stand on the ground under need the mounting plate. Adjust the height of the mounting bracket until the stand can fit snug between the ground and the bottom of the plate. Because this distance is vital to the calibration process, it is recommended that the operator(s) remain in the vehicle while the adjustment is performed by someone else.

   a. Although it is strongly recommended that someone else set the height adjustment while the operator(s) remain in the vehicle, it is realized that this may not be possible in some cases. As an alternative, if only one person will be testing, turn the height adjustment screw one full turn past the 5.21 inch required height. If there are two operators, have the passenger sit in the passenger seat while the driver makes the same one turn adjustment. This should adequately compensate for the added weight in the vehicle.

4. Remove the calibration standard from the van and place it on the ground out in front of the vehicle and centered at 32' 9.75" (10 meters) from the front of the Lexan window on the Laserlux unit. If using the beaded calibration panels, look at the arrows on the bottom to describe the direction in which the panel should face.

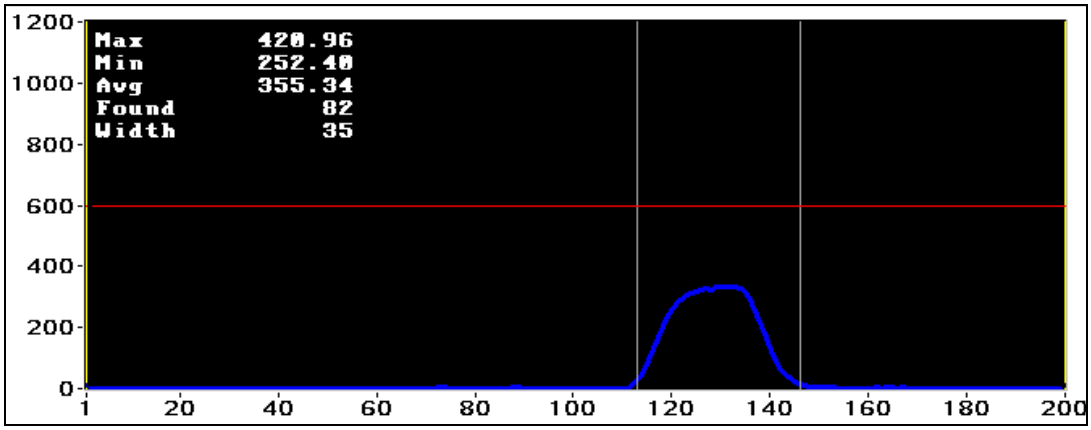
   a. This may be accomplished by inserting 3/8 inch bolt or a screwdriver through the hole at the end of the measuring tape and through the tapped hole in front of the Laserlux on the platform that the Laserlux is mounted to. This is 10 inches from the front of the face of the Laserlux. Thus measure out 31'11.75" to the calibration point.



   b. Ensure that the calibration panel is aligned with the Laser by viewing the panel from the video monitor located near the driver's seat. The panel is aligned, side to side, when the vertical center of the cross hairs, on the monitor, intersect in the center of the stripe. The panel should perfectly align vertically with the center of the cross-hairs. If not, the panel should be adjusted side to side until it is perfectly aligned.

5. With the operator(s) in the van, select *Set-up* and *Tilt Motor Adjustment*. Tilt the laser to locate the calibration standard. The video monitor can be used to determine which direction the tilt motor needs to be adjusted. You will know when you have found the standard as you will see a large bell curve on the screen.

   a. Adjust the tilt motor from just below the sample, up, until the measured retroreflectivity provides a stable reading. When calibrating to a beaded panel, it is beneficial to find the range that the tilt motor is operating in by noting the point when the panel starts being measured and keep tilting until the panel cannot be measured anymore. Make note of this range and try to set the tilt motor somewhere in the middle where the measured retroreflectivity provides a stable reading. You can determine if the position is stable by looking at the *Average* box. Should you have any doubts as to whether the readings are stable, stop and restart the scan. This will reset all of the readings. When calibrating to a ceramic or vinyl block, adjust the tilt motor down until the block cannot be measured anymore. Slowly adjust the tilt motor back up until the laser is stable and reading all of the block or vinyl.



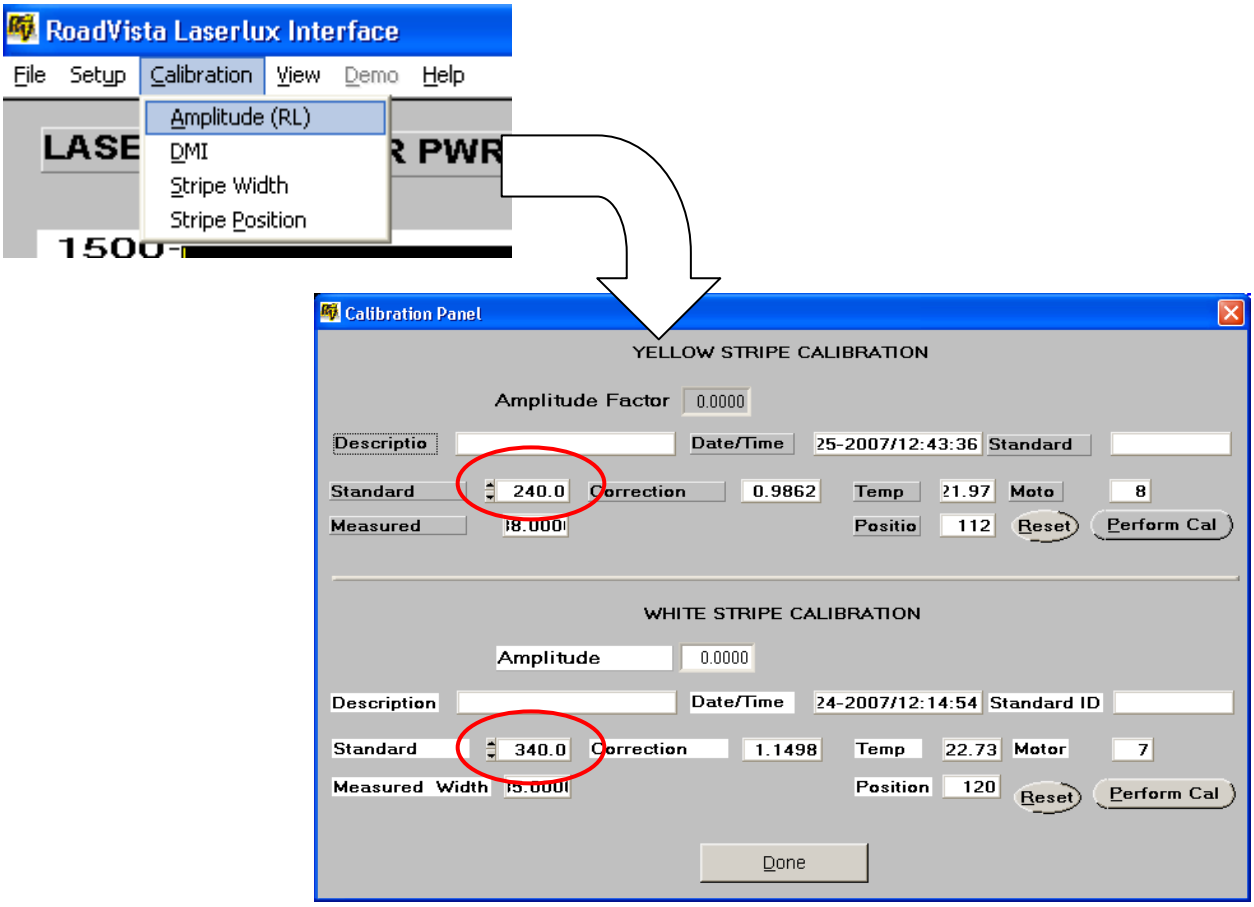
   b. Once you have found the proper position, stop the scan.

6. Set the RPM filter above the retroreflectivity value of the calibration panel that will be used to calibrate to. A good value is about 1100.

7. Click *Stop Scan*. This may generate an Excel file. If so cancel out of the excel file without saving the excel file. There's no need to save this file.

8. Click *LASER PWR ON* to turn on the laser. This allows the laser to stay powered while setting up the calibration.

9. From the main menu, select *Calibration* and then *Amplitude (RL)*. Set the calibration value for the line color you plan on testing.



10. With all operators and equipment placed in the vehicle, hit *Perform Cal* under the calibration color desired. If the calibration panel is something other than a white or yellow beaded panel, make sure that wherever the calibration information is inputted, the same calibration color is selected in the software window. Be careful not to shift any weight in the vehicle during calibration. Once the calibration has been performed, select *OK*.

    a. Check the correction value in the calibration window. It should be between 0.5 and 1.5. If it is not, then you should verify the unit is set up properly and that you have correctly set the RPM filter.

    b. If the correction value is within the specified range. Ensure that whichever value is selected it produces an R_L closest to the calibrated panel value. Close the calibration window to perform a test measurement.

11. Back at the main screen,select *Start Scan* and look at the *Average*. If the unit has been correctly calibrated, your Average should be within +/- 1 % of your calibration value. Be sure that you allow the test to perform for a few seconds to make sure the R_L average does not creep due to the unit is not having reached the warm up period yet. If is the R_L average seems stable and within +/- 1 % of your calibration value, then your unit is properly calibrated. If not, your device needs to be recalibrated.

DMI CALIBRATION PROCEDURE

The MRU has a distance measuring instrument (DMI) mounted to the vehicle to measure the distance traveled by the unit. DMI calibration must be performed at least once per month. Additionally, a recalibration must be performed anytime tires are changed, rotated, or air pressure is adjusted. Calibration is done by driving a precisely known distance on the road. After driving the specified distance, the Laserlux software computes and stores a calibration number. This number equates to the number of pulses recorded by the encoder per distance traveled. Prior to DMI calibration, it is necessary to measure an exact distance along the length of some roadway of at least 1 mile (the longer the precisely measured distance is, the more accurate the calibration would be). Ensure that the beginning and ending points of this section are clearly marked so that they can be easily seen by the operator. This distance needs to be measured only once if this section is used for all DMI calibrations. Fortunately, the Pavement Materials Section of the FDOT State Materials Office already has a "measured mile" specifically used for calibration of the DMI's of its vehicle based testing platforms. This section is located heading West on CR 1474 in Gainesville, Florida and is clearly marked with reflective tape at the starting and ending locations. See Figure 4 below for a map from the State Materials Research Park to the measured mile.

Figure 4 - Map to DMI Calibration Location

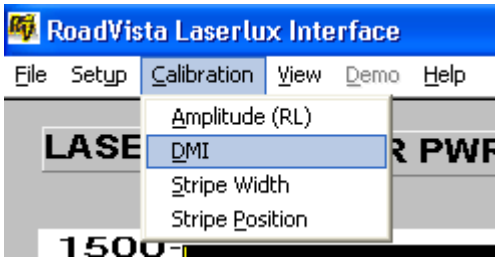
The DMI calibration procedure is as follows:

1. Check the tire pressure. Adjust if necessary to the manufacturer's recommended tire pressure. Make sure to consistently use the same tire pressures for all calibrations.

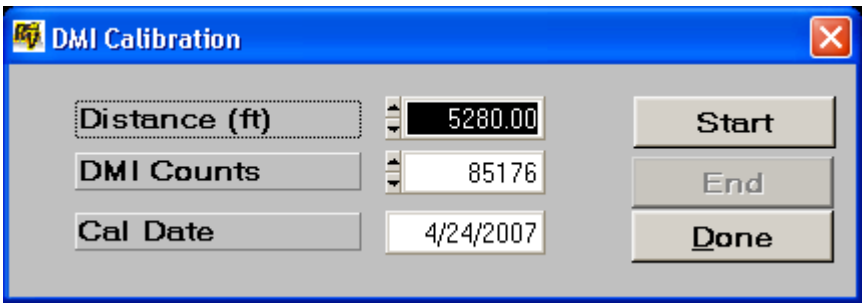
   Power up the Laserlux system as described in previous sections and start the *Road Vista Laserlux* software and turn on the Nitestar DMI system. Note, the Nitestar system has to be turned on to provide a pulse for the *Road Vista Laserlux* software. It is a good idea to have the Nitestar system calibrated for a reference as well. The Nitestar Manual (link) and calibration procedure can be found in the at G:\NDT\MRU\Operations Manual\Nitestar DMI

2. Drive to the start of the measured mile section and stop the vehicle.

3. From the *Calibration* tab of the main menu, select *DMI*.



4. Enter the exact distance of the measured road section you will be traveling in the box labeled *Distance*. For reference, an exact mile is 5,280 feet. This is the value that should be entered when calibrating the DMI at the measured mile site.



5. Click the *Start* button and proceed with driving the vehicle along the length of the measured section.

6. The DMI Counts will incrementally increase as the vehicle travels the length of the section. If the counts are not sequentially increasing, there is most likely a problem with the DMI transducer or wiring. If this is the case, stop the calibration procedure and check all the appropriate connections. Also check the Troubleshooting section at the end of this manual.

7. When you reach the end of the course, stop the vehicle at the exact stopping location and select the *End* button. Record the number of counts in the DMI calibration log book.

8. Repeat steps 3-8 at least 3 times. At the completion of the final measurement, average all of the readings together and round off to a whole number. Use this as your calibration value and enter into the field labeled *DMI Counts*.

9. Your DMI is now calibrated. Click *Done* to end the calibration routine.

10. It is suggested to now drive the length of the measured mile at least once while scanning with the Laserlux software to make sure that the software is getting the correct DMI information.

11. If, for any reason, the DMI counts are reset, the software allows the operator to add a user defined *DMI Counts*. If the calibration values are lost, simply type in the value from the previous calibration. This should only be a temporary fix and a new DMI calibration should be performed as quickly as possible.

VERIFYING ACCURACY OF CALIBRATION STANDARDS

The retroreflectivity values obtained during measurements are solely based upon a calibration factor entered into the accompanying software. These values are calculated based on the measured retroreflectivity of calibration panels. Although, the equipment manufacturer provides a series of 4" calibration panels, the FDOT has created a series of 6" calibration panels. Each panel has a stated retroreflectivity value and direction in which it's measured.

Obtaining an accurate calibration factor is dependent almost entirely on an accurate value of the calibration panel alone (assuming that the calibration has been performed properly). Because the calibration panel uses a stripe identical to what would be placed on the roadway, the same glass beads are embedded in the calibration panel to provide retroreflection. If any of the beads become dislodged from the panel, the retroreflective properties from the panel should and will change. Simply handling the panels can cause this to happen. Thus, it is necessary to routinely verify the retroreflectivity values of the calibration panels.

To properly check the calibration of the panels, you will need to use a handheld retroreflectometer. It is imperative that the same handheld retroreflectometer be used every time to ensure consistency in readings. Currently, the Road Vista Stripemaster is the handheld retroreflectometer used by FDOT MRU personnel for verifying the calibration of the striping.

Procedures to verify the accuracy of the calibration panels are as follows:

1. If the calibration panel appears dirty, clean the panel using dawn dish detergent and a soft scrub brush. Be sure the panel is dry before testing.

2. Obtain the handheld retroreflectometer and calibrate according to manufacturer instructions.

3. Place calibration panels on a flat, non-reflective surface.

4. Set the retroreflectometer onto the calibration panels one at a time with the measurement direction facing the same direction as you would measure with the MRU.

5. Take 12 measurements within the boundaries of each panel. Vary the positions of the measurements so as to get a good average for each panel. Ensure that the retroreflectometer remains flat and level on the panels during measurements and that the retroreflectometer remains parallel with the stripes. In other words, don't turn the device and measure at different angles relative to the center of the test panel.

6. Calculate the average and standard deviation of the measurements and compare with the value from the previous calibration value used. If the results do not match within 5%, re-run the test. If the same results occur, use the average as your new calibration value. If

they differ again, re-run the test. If they are still not matching up, the calibration panel R_L is non-uniform and should be replaced.

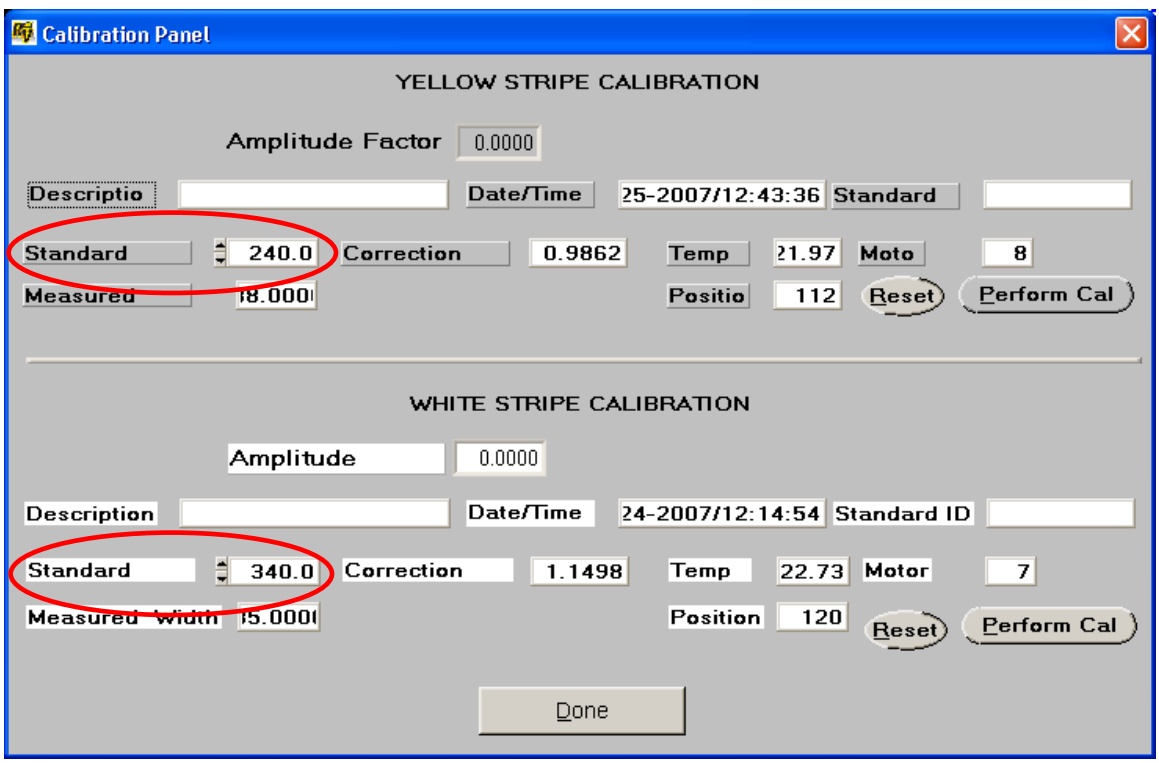
a. Note that your standard deviation should be no more that 15% of your measured value. In other words, if the panel measurements averaged out to 300 mcd/m^2/lux, your panel should have a standard deviation of no more than 45. If this is the case, contact the manufacturer to obtain a replacement panel or another calibration panel needs to be made.

b. If the obtained calibration value is within 5% of the previous value, there's no need to change the value, as the numbers are statistically identical. Anything greater than 5% requires changing the calibrated value.

7. Log the calibrated values, standard deviation, and date in the calibration log for each panel.

8. If the average retroreflectivity of a calibration panel has been modified, open the Road Vista Laserlux software. Select *Calibration* and then *Perform Calibration*.

a. Enter the calibration value in *Standard Value* box and make sure it is saved. This is the new calibration value and will be used as the standard value when a calibration of the Laserlux is performed with that panel.



b. Note that there will be separate Standard Values for a White and Yellow calibration standard. It is recommended that you use the white box for white stripes and the yellow box for yellow stripes. If a ceramic block or black reflective vinyl is as a

calibration standard, it is recommended to enter their information in White Stripe Calibration.

9. Verification of the calibration standard is now complete.

CALIBRATION STANDARD COMPARISON

It was noticed during a stationary creep test that there were major oscillations in R_L data while using a beaded calibration stripe. During the last maintenance of the Laserlux, a new ceramic calibration standard was tested alongside the beaded stripe. Apparently, due to the inconsistencies in the bead placement and the laser point not hitting the same spot on the stripe every scan, there will be large changes in the measured R_L on the beaded stripe. The ceramic block has a nearly static value for the R_L. See the figure below for a plot of the stationary creep test that was allowed to run overnight. The test was setup in a controlled laboratory setting with a nearly constant internal temperature of the Laserlux. There was also a slight downward slope in the R_L of the beaded stripe. This may have to do with changes to the temperature of the stripe that would not occur at the same rate as the ceramic. Tests are being developed to quantify this effect.

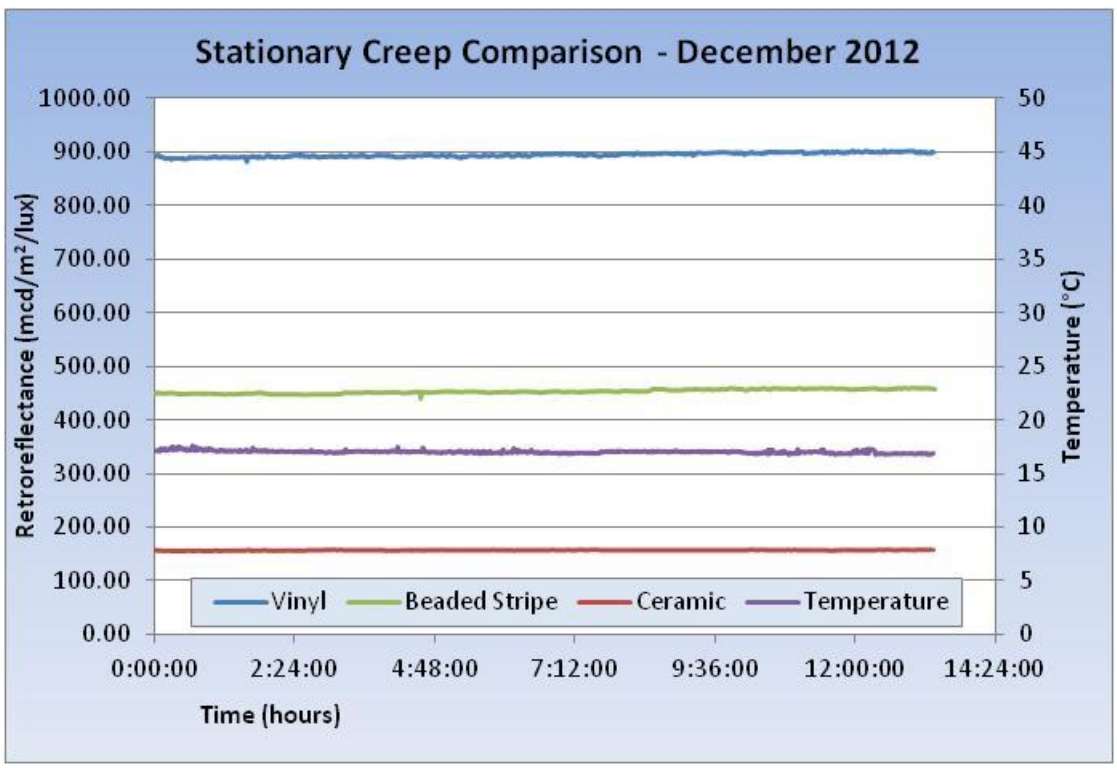


Figure 5 - Stationary Creep Test on Vinyl, Ceramic, and Beaded Stripe

MRU LOGBOOKS

As part of the MRU operation, it is necessary to maintain some sort of record showing what has been done and when so that if a problem recurs in the future it may be easily referenced. There should be at least 3 separate logbooks where valuable information is recorded. The main

logbook will be where all tests are recorded. This book will be used for field and lab testing and daily calibrations and should be with the vehicle at all times. For the verification of calibration standards, a second logbook would contain all of the information recorded in determining the R_L values of the calibration panels. This logbook should be kept with the handheld unit for quick access. The third logbook is the Laserlux Maintenance Log for both units. It should be kept in the lab where lab testing occurs. This logbook is useful in tracking any maintenance and upgrades to the Laserlux units. It would be helpful to record the annual maintenance in this logbook also. The logbook organization is up to the operator's discretion, but it is crucial to maintain accurate records.

Calibration Logbook

- Date
- Roadway tested
- Tilt motor settings
- Side Laserlux is mounted (Driver or Passenger)
- Operators (weight concerns)
- Calibration location (Calibration bay, roadway, etc.)
- Fuel level in vehicle

Verification of Calibration Standards Logbook

- Date
- Date of last calibration
- Handheld measurement device model (ex. AR Stripemaster)
- Photometric Range Testing
- List of measurements
- Standard deviation of measurements
- Average of measurements
- Verification that the new average should be applied to the stripe or if the calibration value can remain the same

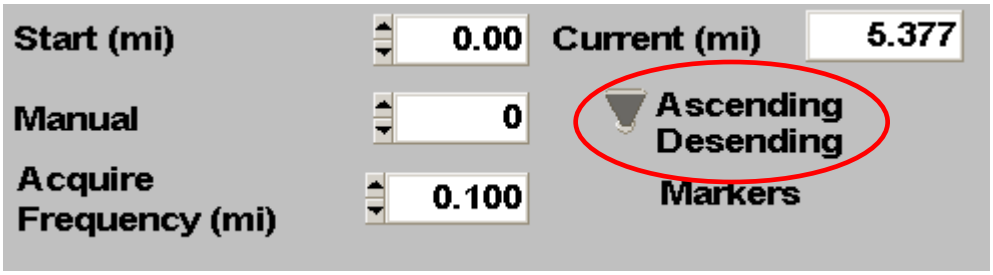
Periodic Maintenance Logbook

- Date
- Component maintenance was performed on
- Any notes about the process
- Was the item fixed or replaced
- Who performed the maintenance
- What unit the maintenance was performed on

SETTING UP A TEST

This section deals primarily with setting up the software to run a test on a stripe. At this point, it is assumed that the unit has been successfully mounted and calibrated. If this is not the case, please refer back to the *Laserlux Mounting Procedure* and/or *General Calibration Procedure* for further instructions. Also, provided in the Appendix is an operator checklist for pre and post testing procedures.

1. Determine the direction that you will be traveling when you collect data. Use a Straight Line Diagram (SLD) to find out if your mileposts will be ascending or descending based on the travel direction. Ascending would be travel in the North or East directions and descending would be travel in the South or West directions. Set the toggle switch on the control panel accordingly.



2. Set the *Acquire Frequency* for the run. Most of the time, 0.1 mile intervals are adequate for typical testing. If you are testing experimental sections which may be short in length (<1mile), you may wish to reduce the interval to 0.05 miles or less.

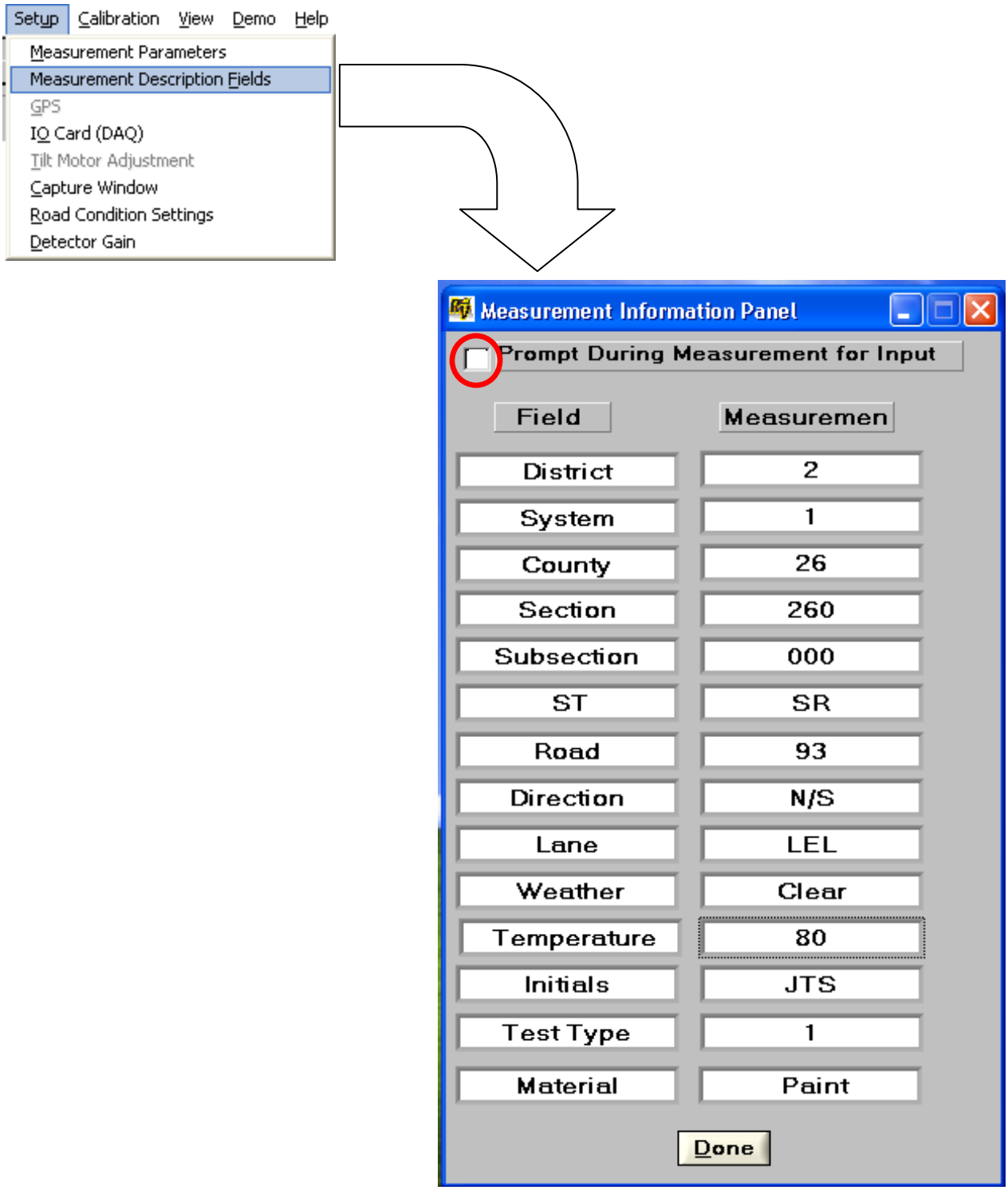
   a. Keep in mind that you want to ensure you are getting at least 30 retroreflectivity readings in each interval. If you are getting less, you need to increase your acquisition frequency or decrease vehicle speed.

   b. See the section *Vehicle Speed with Regards to Stripe Type* for information on changing the acquire frequency for different types of lines.

3. Select the button of which calibration stripe that will be applied. If colored beaded panels were used to calibrate the equipment, select button to indicate the line (white or yellow) that testing to. (Note that they should be the same color).

4. Set the RPM filter above the retroreflectivity value that is planned for. A good value for most roadways when scanning any centerlines or edgelines is about 600 to 800. If skiplines are being scanned, it is important to set the RPM filter to a value that is just above what the skipline stripe is being measured as. This will prevent high peaks in the data from scanning the RPM that may have values well above 2000 mcd/m^2/lux.

5. Information related to the current test is to be added to the *Measurement Information Panel* by selecting *Measurement Description Fields* from the setup menu. A detailed description of each field is listed below. If the *Prompt During Measurement for Input* box is checked, The *Measurement Information Panel* will be displayed after the *Start Scan* button is pressed. It is suggested to add the information manually, before hitting the *Start Scan* button though, to avoid input errors during a test.



a. *District:* Enter the district that the test is being run in.

b. *System:* Enter the system number of roadway being tested.

1. Primary
2. Secondary
3. Toll/Turnpike
4. Interstate

c. *County:* Enter the county number of the county being tested.

d. *Section:* Enter the road section number

e. *Sub Section:* Enter the subsection number – if there is no subsection the default will be "000".

f. *ST:* Enter either the *SR* (State Route) or *CR* (County Route)

g. *Road:* Enter the State Route or County Route number

h. *Direction:* Enter either *N/S, E/W, N, S, E* or *W*

i. *Lane:* Enter the lane in which is being tested

j. *Weather:* Enter either *Sunny, Clear, Overcast* or *Cloudy*

k. *Temperature:* Enter the temperature of the outside environment

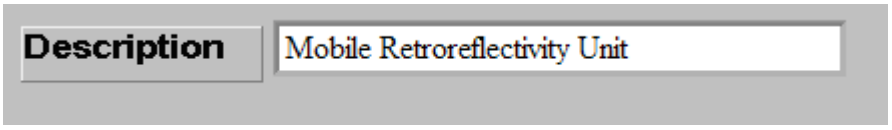
l. *Operator Initials:* Enter the operator's initials

m. *Test Type:* Enter the test number of roadway being tested.

1. Inventory – Old Striping
2. Special Request
3. Overlay
4. New Construction
5. Retest

n. *Material:* Enter the material of the line marking. Ex. *Thermoplastic* or *Preformed Tape*

6. Any additional testing information that was not covered in the *Measurement Information Panel* can be entered in the *Description* field. If there are any Operator's notes specific to the job, the *Description* field is where to enter that information.



7. Determine where your starting location will be. It is often helpful to use the SLD and find the nearest intersection close to where you would like to begin your test. Set the chainage to the mile post at the beginning of your test.

8. You are now ready to begin testing with the Mobile Retroreflectometer Unit.

PAVEMENT STRIPE NOMENCLATURE

A standard naming convention was devised to identify each pavement stripe regardless of the number of lanes. Table 1 shows an explanation of the nomenclature used.

Table 1 - Pavement Stripe Nomenclature

Purpose	Code	Description
Direction	L	Southbound or Westbound direction of travel
	R	Northbound or Eastbound direction of travel
Stripe Type	EL	White edge line
	CL	Yellow center line. **All** yellow stripes including yellow skip lines are considered as center lines.
	SL	White skip line. A number is placed between the Direction and the Stripe Type to indicate the order of the skip lines starting with the one closest to the center line

The pavement stripe nomenclature includes the direction (L or R) followed by the stripe type (EL, CL, SL) as indicated in table 1. For skip lines, a number is inserted between the direction and stripe type. As an example, the northbound skip line closest to the center line would be named R1SL, while the edge line in the same direction would be named REL. The following four figures show examples of the naming convention for several different scenarios. Consider the right lanes to be running north or east for all examples.

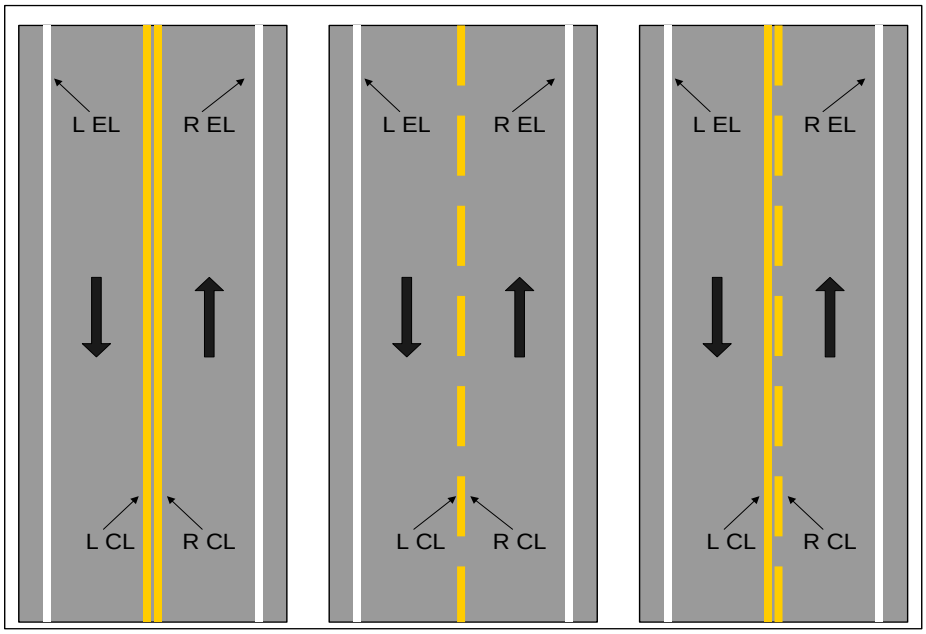


Figure 6 – Pavement stripe nomenclature for 2 lane undivided road

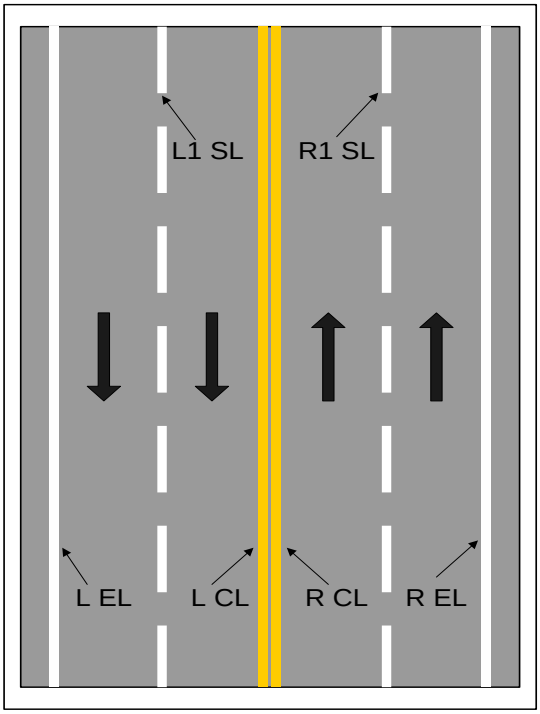


Figure 7 – Pavement stripe nomenclature for 4 lane undivided road

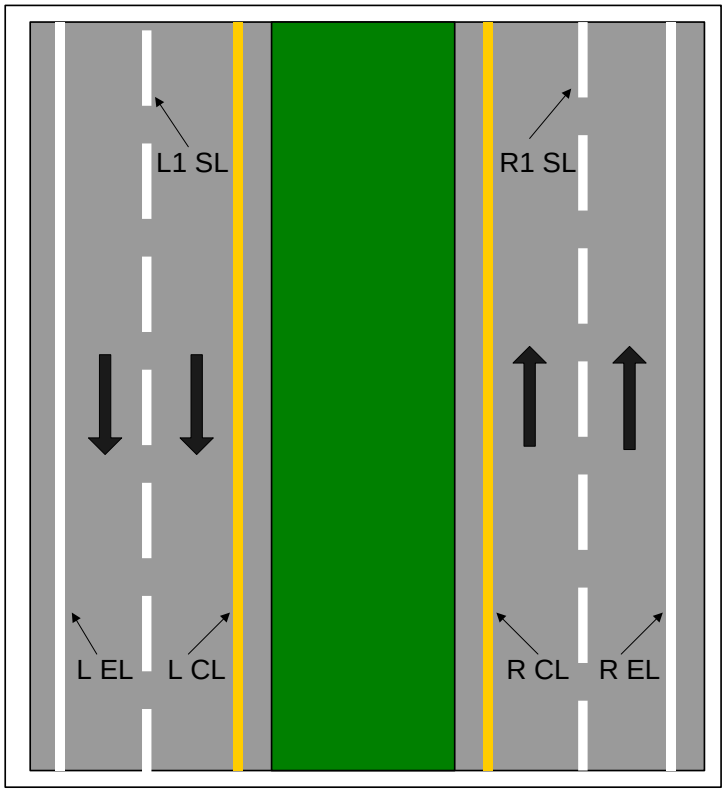


Figure 8 – Pavement stripe nomenclature for 4 lane divided road

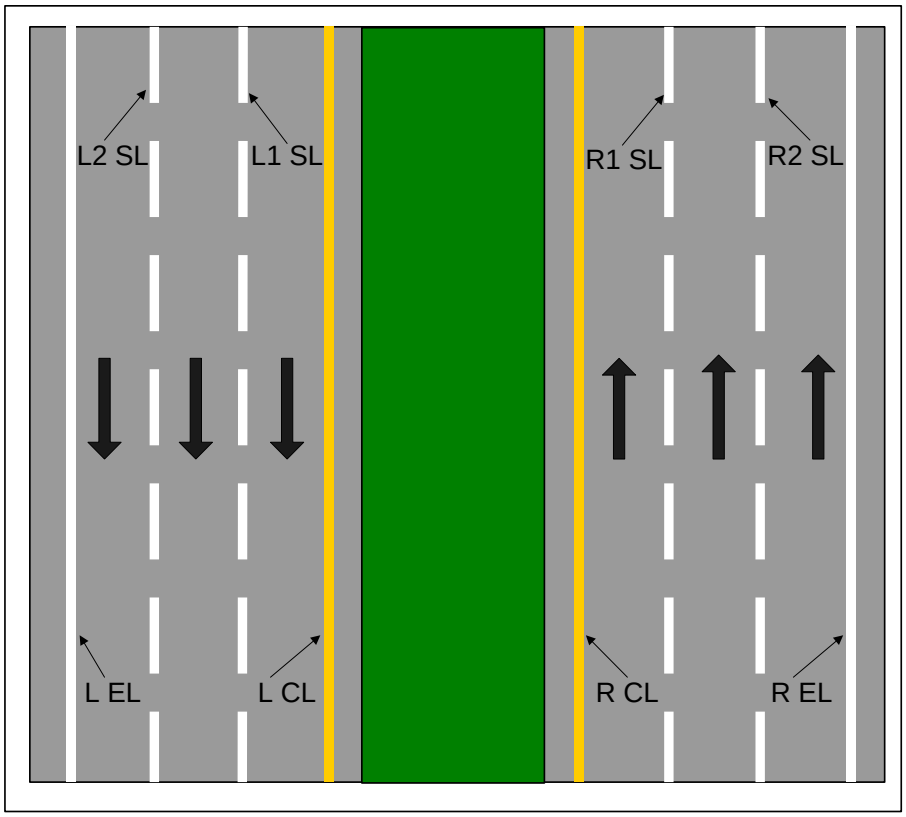


Figure 9 – Pavement Stripe nomenclature for 6 lane divided road

TESTING WITH THE MRU

By now, it assumed that you know how to mount the unit, perform a calibration, and set up a test. The next step is to go out in the field and successfully collect data with the unit. The MRU is a sensitive unit and there are many important factors to be aware of which can cause errors in the data acquisition. Following the established protocol will help minimize these issues. Most of the procedures that the Florida Department of Transportation has in place to ensure accurate data are supported by other state and highway agencies, as well as private contractors owning the same type of equipment. These procedures have been developed based upon thousands of hours of laboratory and field studies of the equipment sensitivities to various effects.

WHEN *NOT* TO OPERATE THIS EQUIPMENT

Before discussing how best to collect data, it's important to understand when not to test with the unit. Because pavement markings use spherical beads embedded in the striping material to reflect light back to its source, retroreflection will not occur when there is significant moisture or standing water covering the striping. The physics behind this phenomenon are explained with the aid of the two figures below.

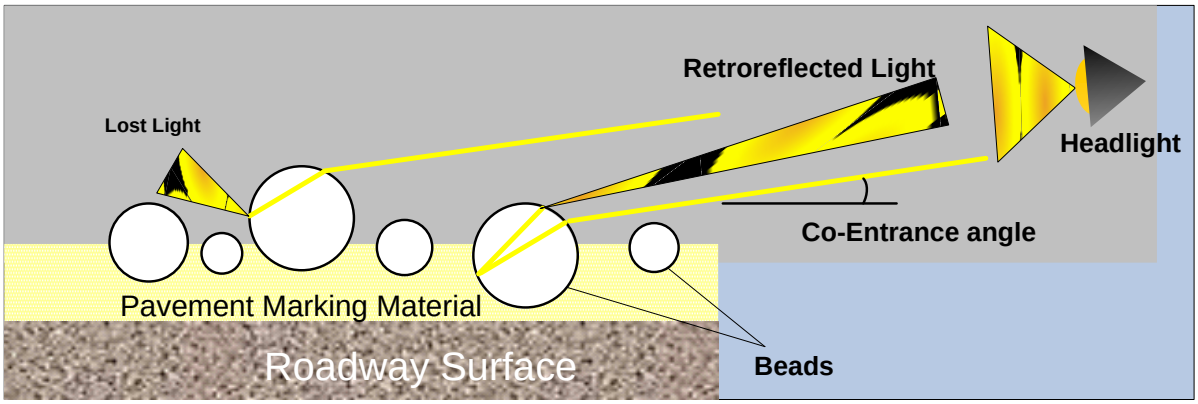


Figure 10 - Physics of Retroreflection

Figure 10 shows the concept of retroreflectivity on pavement striping. Light from a vehicle's headlamps projects outward and arrives at the glass beads. The light then travels into the bead and refracts inward toward the marking material. Then the light is reflected off of the material and sent back into the direction of origin. Beads that are embedded too deep or not deep enough will cause light diffusion, reducing the pavement marking's visibility.

The illustration in figure 11 demonstrates what happens when water covers a stripe. In coming light from the headlamp now hits the water and not the beads. Since standing water does not form the same spherical shape as the glass beads, the source light now bounces off the surface of the water (specular reflection) away from the headlamps, thus causing an effect opposite to the one desired. Because light reflects away from the source, the markings are not seen as well.

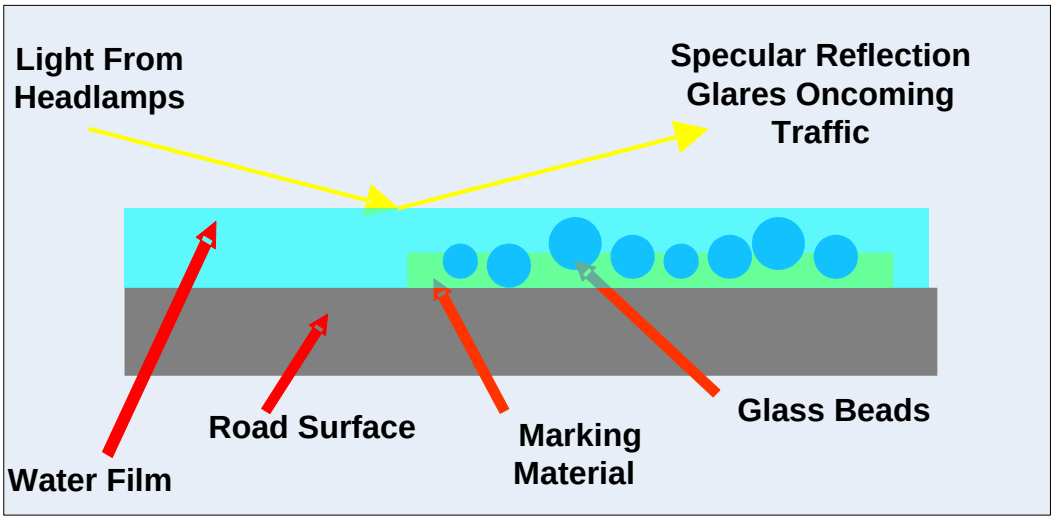


Figure 11 - Effect of Water on Measurements

A laser line is used as the light source in the MRU instead of headlamps, but this makes no difference on the outcome. Laser source light will still hit the water and reflect away if there is standing water or significant moisture on the stripe. Because no light is reflected back, the Laserlux will not detect any.

Moisture that is in the air, whether it be rain, sleet, snow, or fog (also smoke) will also result in low or no readings. These environmental effects will cause the source light to diffuse before hitting the stripe. In other words, as the light reflects off of suspended particles in the air, the amount of light that hits the stripe would be only a fraction of what it would be if there were no particles in the air. If less light is making it to the stripe, less light will be reflected back. The Laserlux will not "know" if less light is reaching the stripe though, and R_L readings will be much lower and not accurately represent the R_L of the stripe.

For the reasons outlined above, it is very important for the operator to be aware of all ambient environmental conditions. For example, if it rained in the testing area the night before, the road may not be dry until the sun has been out for several hours. Also, if possible, it's recommended to test East/West roadways first before testing North/South roadways to allow the shaded spots to dry on the Northbound roadway. If test are taken on stripes that are still wet, lower R_L readings will result. Also, it is recommended that the MRU be equipped with a digital psychrometer to measure ambient temperature and humidity.

TEMPERATURE EFFECTS WITH THE MRU RESULTS

The MRU uses advanced optic and electronic devices to measure the amount of reflected light received from pavement markings. Some of these devices are known to be sensitive to temperature changes, and as a result, the data can be significantly influenced. Fortunately there are corrective actions in place to control the influence of temperature of these devices. It is important to be aware of these corrective actions in the event that they are not working as designed.

Two major actions have been taken to ensure accurate data collection regardless of temperature effects. The first action was to add a thermoelectric cooler with a higher load capacity. The original cooler could not keep up with the internally generated heat load in conjunction with the external heat load (solar) acting on the Laserlux. Originally the cooler came with an analog controller. This controller was not sufficient at maintaining a narrow temperature range within the box. A solution to this was to purchase a TC 3300 Proportional Integral Derivative (PID) controller for the thermoelectric cooler. The new controller allows for a user-defined temperature set point. Since the controller installation, a temperature range of ±2º C has been possible to sustain.

The second major addition to control temperature effects was the update to the software. The new temperature compensation factor input in the Laserlux software allows user defined factors to be input based on results of a stationary creep test. A stationary creep test involves setting up the vehicle in the calibration bay (or other laboratory setting) and allowing a scan on a particular stripe starting from a low temperature. The stripe is scanned without the thermoelectric cooler running or any software temperature corrections for a few hours (or until the desired maximum operating temperature is reached). See Appendix A for instructions on how to perform the temperature compensation testing (stationary creep).

For a complete breakdown of the testing procedures to determine temperature stability of the Laserlux refer to the TRB (Transportation Research Board) paper submitted by the SMO entitled "*Characterization and Mitigation of Temperature Sensitivity within a Mobile Retroreflectometer Unit (MRU)*".

VEHICLE DYNAMICS VARIABLES

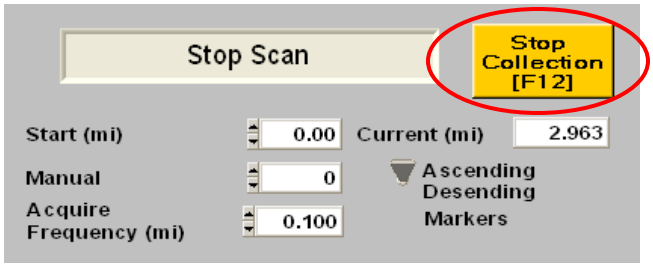
The Laserlux was designed to actively accept measurements between 8 and 12 meters in front of the vehicle. Even though the design of the Laserlux accepts this geometry, it is recommended to try to maintain as constant of a speed as possible, minimizing quick braking or acceleration. A test has been created that simulates the effects of braking and acceleration. It is wise to check that the Laserlux is consistently reading within this design range at least once every two months.

Braking Effects

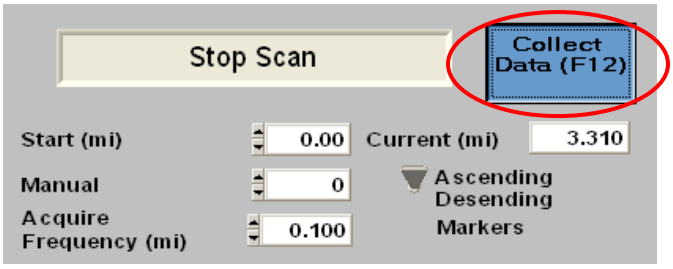
When the brakes are applied during testing, the unit will be collecting data closer to the 8 meter geometry. This will be acceptable as long as it only happens once or twice per file write. The averaging in the software should average out any incorrect readings. It is suggested to minimize braking as much as possible, although it may be unavoidable at times.

Stopping Effects

When stopping or braking for an intersection during a test, the unit will not just be collecting a couple data points closer to 8 meters but may remain stopped for a short period of time. This can relate to a single point of the pavement marking having a significant influence on the averaging in the software due to being stopped. It is suggested to minimize this effect by pressing the *Stop Collection* button in the software.



This will keep the DMI and software running but no data is collected while the button is pressed. Once the vehicle has began moving again, the *Start Collection* button can be pressed again to continue collecting data.



Acceleration Effects

When accelerating during a test, the unit will be operating closer to the 12 meter geometry. As with braking, there should not be a large deviation in measurements, but the operator should try to avoid acceleration effects as much as possible.

VEHICLE SPEED WITH REGARD TO STRIPE TYPE

Edgelines &Centerlines

For edgelines and centerlines, the MRU can take measurements at up to 60 mph (~96 kph). It is not recommended to exceed 60 mph unless necessary. The higher speed you travel, the less data is collected per file write. This means less resolution in the data, but as long as there is at least 30 data points per file write the data is considered to be reliable.

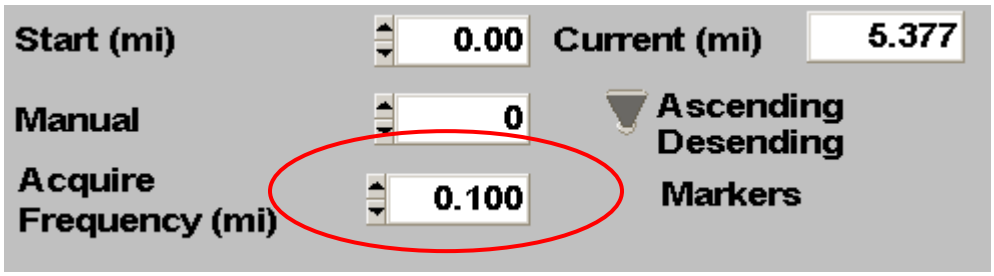
Skiplines

Skiplines are spaced apart in two different configurations. There is the 10/30 skip that is a 10 foot skipline and 30 feet of space to the next skipline. There is the 20/20 high contrast skip which is a 10 foot skipline, a 10 foot black line, and 20 feet of space. Regardless of the type of skip, there will still be only 10 feet of line to scan for every 40 feet of roadway. This translates into 132 skiplines per mile. At 60 miles per hour the Laserlux can perform about one scan every 4.5 feet (20 scans per second), so at high speeds it can be difficult to collect a large enough sample of data points for an accurate representation of the skipline retroreflectivity but, as mention, as long as there is at least 30 data points per file write the data is considered to be reliable.

There are two things that can be done to accommodate skipline readings. The first and easiest action would be to drive slower. This will cause more scans per file write, but will still allow data collection in 1/10 mile increments. This method is ideal, but slowing down on a high speed

facility may be dangerous to the operator and driving public, so only use this method on roads with lower speed limits and lower traffic volume.

The other method to help with skipline data collection would change the acquire frequency of the software.



The acquire frequency tells the software at what change in distance to log the collected data. If the frequency is set higher (1/5 mile or 0.200 mile) there will be a greater chance of collecting more data points per file write, which will help with the averaging of the R_L. This method will be useful on higher speed facilities where slowing down is not possible and this is only suggested for experimental projects. Also, this higher acquire frequency can be used on long stretches of roadway with little change in striping uniformity.

Road Conditions and Event Codes

Pavement markings can have a lot of different variable that need to me handled appropriately to represent the accurate reading of the stripe. Not only does operator need to understand the influence of acceleration, braking, and stopping but there are pavement changes, intersection, turn lanes, etc, called event codes, which need to be marked as well. The operator should understand the importance of event codes and how important it is to have them accurately marked.

Event Codes (F functions)

1. Pavement Change – Should be marked when pavement changes. This allows the separation of data at the point in case a new pavement and pavement marking has been applied.
2. Intersection – Should be marked coming into an intersection which can relate to high traffic areas as traffic driving on top of the pavement marking while it is making a turn.
3. Through Town – Should be marked when coming into a heavy traffic area with lots of traffic lights and accelerating and braking.
4. No Line – Should be marked when no line is available to test on yellow and white lines.
5. Bridge - Should be marked at the beginning and end of the bride. Similar to pavement change, this allows the separation of data in case a different pavement marking applies.
6. Turn Lane – Should be marked when a turn lane is of the same color as the stripe being tested. This is used mostly on the white edge lines for all the right hand turn lanes. NOTE – When testing the yellow center line, it is best to use the *Stop Collection* (*F12*) key so that the white line of the turn lane does not influence the center line data.
7. Damage/Debris on Line (significant, <.05mi) – Should be marked when a section of the line is damaged or has significant debris on it for more than 0.05 miles. This could be due

to something scrapping the pavement marking away while it is drug down the road or heavy grass, dirt, other paint, etc, are covered over the pavement marking.

8. Construction Zone – Should be marked if construction is taking place on the pavement marking you are testing. This should be marked at the beginning and end of the construction zone and if the software does not cut out the data, the *Stop Collection* (*F12*) function should be used or it should be taken out manually.
9. Pedestrian Interference - Should be marked if the vehicle has to maneuver around a pedestrian to continue testing at highway speeds.
10. Break – Should be used when needing to mark the data in the instance it may need to be taken out and used for another reason.
12. Stop Collection – Should be used in the application previously mention when chainage need stay on but data does not need to be collected and influence the accuracy of the stripe being tested.

AVOIDING THE MIDDLE LANE

On six-lane highways, there will be a special way to scan the roadway that will be safer for the operator and the driving public. In a six-lane situation, there will be the possibility of collecting data from the middle lane between the travel and passing lanes. This can be a dangerous situation because the MRU collects data at a slower speed than the posted speed limits on most high speed facilities. A plan has been developed to avoid testing in the middle lane. Refer to the Figure 12 below. The numbered arrows at the bottom of the figure indicate the order in which the lines should be scanned. Arrows 1 through 4 should be scanned with the Laserlux on the passenger side of the vehicle. After these lines are scanned, switch the unit to the driver's side of the vehicle (recalibrate, of course) and run the lines on arrows 5 through 8. This will help avoid potential accidents and the vehicle from being passed on both sides by large trucks.

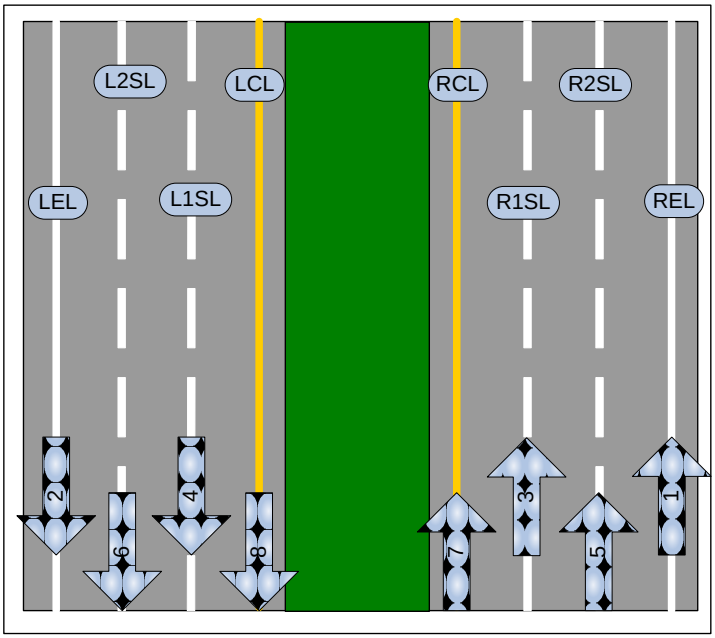


Figure 12 - Method to Avoid the Middle Lane

DATA POST PROCESSING

EXAMPLE DATA

See Appendix C for example data that was recently collected on a 2-lane undivided highway

LASERLUX MACROS FOR USE WITH MICROSOFT EXCEL

See Appendix C for screen shots and description of current summary output macro.

RETROREFLECTIVITY DATABASE

A Pavement Marking Management System (PMMS) Database has been developed to store the retroreflectivity data into the Roadway Characteristics Inventory (RCI) as code 456, pavement marking retroreflectivity values. The database is fully web-based and can be accessed with a valid RCI user account and can provide features such as downloadable Excel files, video imagery, and GIS applications. The RCI Database is a good tool for District Maintenance to look and see current pavement marking data. The RCI-PMMS Users Guide (Link) can be found at: G:\NDT\MRU\Operations Manual\MRU Database

However, the RCI does not allow for extraction of historical data and the data can only be queried for a single County Section at a time at this time. Due to these reasons, the RCI-PMMS database is not the most appropriate database for performance based striping.

Therefore, the SMO has created an in-house, Excel-based database that provides more flexibility. It allows for retrieving historical/current data with more options and provides plots of the MRU data. The SMO-PMMS Database can be found on SMOs SharePoint at:
http://smsharepoint.sm.dot.state.fl.us/sites/SMO/pavement/performance/Mobile%20Retroreflectivity/Forms/AllItems.aspx?RootFolder=%2Fsites%2FSMO%2Fpavement%2Fperformance%2FMobile%20Retroreflectivity%2FSMO%20Database&FolderCTID=0x012000F80DA1763F106A47AB2E28E1E14080F0&View={E6C61D80-4DFB-431C-BA8E-A19EFE0701DC}

However, since Excel is not the best environment for storing large amount of data, the in-house database is viewed as a short term solution until a better database is identified and implemented. Discussion is still on-going as to which database should be used. As of date, it is desired that the new database be GIS (and possibly LIMS) compatible and be connected to the Traffic Marking Certification (Worksheet) form # 700-050-70) and its data.

MONTHLY MAINTENANCE PROCEDURES

LASER ALIGNMENT

Once every two months it is suggested by the manufacturer that a laser alignment be performed unless a problem occurs. The best way to describe this maintenance process is to watch a video that was created during one of the Gamma Scientific maintenance visits. The video is found on the G drive on the SMO intranet. The video can be located here:
G:\NDT\MRU\Library\Laserlux Alignment

The object of the laser alignment is to ensure that the laser is seen within the view of the photodetector. The cover of the unit must be removed and the photodetector removed. A scan should be run before checking the alignment to ensure the center position of the software at the 10 meter distance. The spinning mirror should then be unplugged as well. The concept for alignment is to use an alternate light source in a reverse direction. This is achieved by forcing light thru the photodetector location thereby creating a foot print at which the laser should center on.


In the above captions a separate source light (a LED flashlight can be used) is used to project light thru the viewing area of the removed detector. A white board is positioned at 10 meters to display the detectors viewing area. After sending the light source thru the detector, the laser is turned. The detector should be located at the center position marked from the software center. In the picture below, the laser is seen within the detectors sight. For a perfect alignment, the laser must be centered within the detectors viewing area and have a level scan.


Aligning the Laser and Detector
If the laser is not located in the center of the detector viewing area, adjustments need to be made to the alignment mirror. Located in the front of the Laserlux unit are four 3/8 inch locknuts. When aligning the laser to the detector, be sure to only adjust in either the vertical direction or horizontal direction (DO NOT make adjustments to all four locknuts at the same time). Make small incremental adjustments to the locknuts by loosening one locknut, then tightening the other locknut in the direction that the laser needs to be aligned. Be sure to make very small adjustments.

Vertical Adjustments
To adjust the laser upward into the center of the detector area, loosen the bottom locknut in increments as the top locknut is tightened. To adjust the laser downward into the center of the detector area, loosen the top in increments as the bottom locknut is tightened.

Horizontal Adjustments
To align the laser horizontally, loosen the locknut incrementally opposite of the direction the laser needs to be adjusted as the locknut in the direction the laser needs to be adjusted is tightened.

Level Laser Scan
Check the laser for a level scan with a 4 foot digital level (or level of appropriate size) at the 10 meter distance. With the level applied at the 10 meter distance adjust the tilt motor at a height just above the level for accurate measurements. With the light source projecting through the detector, check for the detector area to scan parallel with the digital level. If the detector is scanning in an unlevel manor, Gamma Scientific needs to be contacted. If the detector is level and the laser is scanning in an unlevel manner the mirrors need to be adjusted. First, adjust the alignment mirror so that the laser scan is parallel with the digital level. Locate the position of the detector area from the laser. One of the two redirecting mirrors needs to be adjusted to realign the laser in the detector area. If the laser seems to be centered in all mirrors, the alignment needs to be adjusted to the last redirecting mirror. Two 3/8 inch locknuts can be adjusted in a similar manor as the alignment mirror. If the laser does not appear to be in the center of the rotating mirror (or mirror in the path after the rotating mirror), the adjustment needs to be made to the first redirecting mirror.

CHECKING PHOTODETECTOR AND INTERFERENCE FILTERS

Below is a schematic photograph of the photodetecting unit.

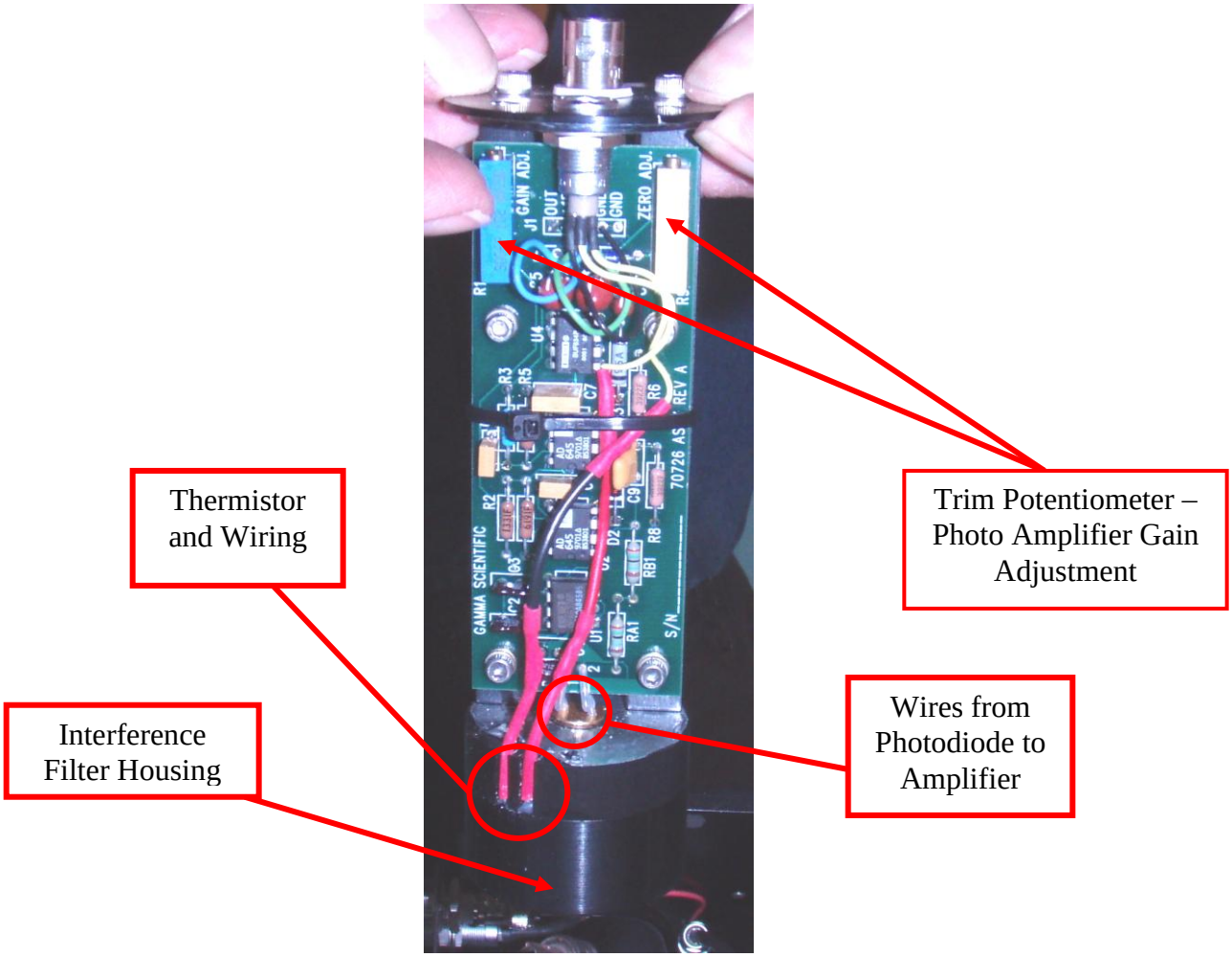


Figure 13 - Photodetector Unit

It is suggested to periodically check the interference filters during the laser alignment procedure. When removing the filters, be very careful not to touch the surfaces due to potential deposition of dirt, fingerprints, or other fine particles that may alter the optical efficiency of the filters. When the filters are removed try to check if they are hazy when held up to a light. The filters have a lifespan of 2 to 3 years. Once a filter becomes hazy, it will exhibit a decline in its ability to filter the proper wavelength of light and data may be corrupted. If this happens, replacement filters can be found in the MRU calibration and Gamma Scientific needs be contacted to to order replacement filters.

Clean Mirrors – Spinning and Stationary

When cleaning any optical system, it is important to be careful that none of the lenses or mirrors is scratched in any way. This can cause laser beam diffusion, resulting in a loss of data. In the Laserlux unit, the mirrors are surface coated. This means that the reflective coating can easily be scratched or removed with minor abrasion from cleaning cloths or products. It is suggested to use a non-invasive technique when cleaning mirrors if needed. A cleaning duster (like the ones used for cleaning computer equipment) can be used to remove visible particles off of the mirror surfaces. If this method does not clean the mirror well, it is recommended to use scotch tape

when cleaning the mirrors. The tape can carefully by apply then removed using latex gloves. This step may need to be repeated until mirror appears free from film.

MAINTENANCE LOG

Anytime maintenance is performed, be sure to make a note of it in the maintenance log. The maintenance log should be kept near the Laserlux, either in the van or calibration bay. For more detail, please see the section entitled, *MRU Logbooks*.

TROUBLESHOOTING

POWERING THE LASER

Laserlux box is not receiving power

1. Check the cable connections between the van and laser box. Ensure that connections are secure.

2. Test the continuity of all pins in main cable. Replace if necessary.

3. Check the power level of the MRU main battery. The Laserlux requires power from this battery.

4. Check the power level of the MRU rear battery, located either inside the van near the video log equipment or under the side sliding door mounted to the side of the chassis. If the inverter shuts down with a low voltage warning (an audible beeping), the battery needs to be charged or the MRU will have to be plugged in to build up power.

5. Check the two fuses located at the sides of the Laserlux box. Always replace these fuses with fuses of the same amperage (5A). **NOTE:** Make sure to check for isolated problems that might be mistaken for power failure, such as lack of power to the spinning mirror or the laser is too cold to work. See the following sections.

Spinning mirror in Laserlux will not spin

1. Check the connection of the main cable between the van and Laserlux box.

2. Test the continuity of all pins in the main cable. Replace if necessary

3. Reboot the entire system.

4. Check the two fuses located under the laser interface card on the rear of the laser.

5. Check the connector located on the black vertical mounting plates inside the box. The connector is a serial port (RS232 9-pin) attached to a ribbon cable. When removing the Laserlux cover, this connector can be disconnected with a small Phillips head screwdriver.

Laser will not turn on, but spinning mirror is on

1. Check the main cable connection between the van and Laserlux box.

2. Test the continuity of all pins in the laser cable. Replace if necessary.

3. Ensure the laser is within the operating temperature range (0˚C to 45˚C).

4. Open the Laserlux box. Using a multimeter, check the black and red input voltage wire to the laser power supply. **CAUTION:** *Do not touch, test, or disconnect the 2-pin white laser connector. This connector has* ***6000 volts*** *AC running through it*. ALWAYS power down the laser and then disconnect it before checking the laser power supply output.

CALIBRATING THE LASER

Standard deviation is higher than normal during calibration

1. Check the standard deviation of the calibration panel by taking 12 retroreflectivity measurements with an approved handheld retroreflectometer. Compute the average and standard deviation of those measurements. If the standard deviation is more than 15% of the average value of the panel, a new calibration panel should be procured. Remember that the accuracy of the measurements can only be as accurate as the calibration standards.

2. Check the optical alignment of the laser. If one side of the spinning mirror is projecting the laser spot completely inside the rectangular return aperture while the other side is projecting only a portion of the spot in the same box, the standard deviation will increase. Perform an optical alignment and re-check the standard deviation during calibration.

3. Check the cleanliness of the spinning mirror and optics. If one side of the spinning mirror is cleaner than the other, measurements will vary more. **CAUTION:** When cleaning the spinning mirror, do not apply too much pressure because the mirror can be misaligned if moved less than 1/1000 of an inch. Also, the mirrors in the Laserlux are surface coated mirrors. This means that the surface is very sensitive to scratches. A good method to clean the mirrors is to use a computer duster (compressed air in a can) to remove visible particles off of the mirror surfaces. If this method does not clean the mirror well, it is recommended to use scotch tape when cleaning the mirrors. The tape can carefully by apply then removed using latex gloves. This step may need to be repeated until mirror appears free from film. *Make sure to perform an optical alignment after cleaning the optics.*

4. Check the amount of bounce in the laser line path across the calibration panel. Any bounce in excess of 5 inches will cause a higher than normal deviation in the measurements. Perform an optical alignment to rectify.

Temperature sensor is not reading the correct internal temperature

1. Remove the Laserlux lid enclosure and measure the temperature at the base of the optical amplifier with an infrared temperature probe or equivalent.

2. Check for loose connections between the thermistor and optical amplifier assembly. Repair or replace if necessary.

3. Check that there is a sufficient amount of thermal conductivity paste in the hole that the thermistor is seated. If there is not enough, add a generous amount but be sure that none of the paste gets on or near the photodetector electronics or interference filters. This will

ensure good thermal contact between the interference filter housing and the thermistor, allowing for more accurate temperature readings.

4. Check the for low vehicle voltage. If the vehicle has low voltage from a battery or alternator failure, it can create errors in the MRU software.

Laserlux will not calibrate on a cold morning

1. The optical devices and lenses in the Laserlux will be covered in condensation if the unit is removed from a temperature controlled environment to a warmer, more humid environment. Allow the Laserlux to warm up for at least fifteen minutes before calibrating.

2. Do not attempt to calibrate the unit if the internal temperature is below 10ºC. The characteristics of the optical electronics will be altered as a function of temperature. They need sufficient time to warm up and reach a steady-state condition. It will be very difficult to maintain a temperature below 10ºC, so it is suggested to try to calibrate in the range of 20 to 30 ºC.

Tilt motor will not move

1. Make sure that the Laser is turned on (in software) and power is being supplied to the Laserlux unit.

2. Check the data cable connections between the van and Laserlux unit.

3. Test the continuity of all data cable pins with a multimeter. Replace if necessary.

4. Check the mechanical connections of the stepper motor located at the rear of the Laserlux.

5. Check the electrical connections between the four stepper motor wires to the driver board located under the laser interface card.

Alignment camera does not line up with laser

Frequent optical alignments may change the position of the alignment camera in relation to the laser. To avoid this, never move the laser measurement area. Always adjust the mounts of the bore sight camera by loosening the two adjusting screws on top of the camera for right and left adjustment.

No optical signal in Laserlux software

1. Check the main cable connection between the van and Laserlux box.

2. Test the continuity of the main cable pins. Replace if necessary.

3. Use an oscilloscope to verify the presence of an electro-optical signal from the output of the optical amplifier (this must be done when the software is telling the Laserlux to scan –

otherwise no signal is coming through). Once you are sure that the problem is not an electrical connectivity issue, move on to the computer and/or software.

4. Reboot the computer and look for the message *DAS 1802 D/A Board Found.* This board controls the Laserlux. If the computer does not recognize this card, technical assistance will be needed. Vibrations can cause connection problems inside the computer and communication between the card connections is interrupted. Wiggle all computer cards (PCMCIA Card) gently to see if the problem is replicated in doing so.

Data from the Laserlux has single stations that plot the R_L in the thousands

Intense shock in the van (hitting large bumps, etc.) can cause the computer system to lose its timing and communication signals, causing the miscalculation of the station average.

1. Remove the PCMCIA card from the computer.

2. Clean the edge of the card connectors and computer slots. A can of computer duster is recommended for the computer slots.

3. Reinstall the cards and make sure that they are screwed in tightly.

Laserlux is measuring stripe retroreflectivity very low

1. Make sure the Laserlux is operating within its specified temperature range. If the interference filters temperature changes from the calibration temperature, there may be a shift in the wavelength that is transmitted through the filters. This problem can be offset by recalibration. It has been seen that a 1 C temperature change can cause up to a 5% change in the measured R_L.

2. Check the Lexan plates for excessive scratching, dirt, or bugs. Clean the Lexan regularly with some type of glass cleaning solution. Also, between tests, check the Lexan to make sure that the surface is not contaminated.

3. Check the thermoelectric cooler at the bottom of the photodetector casing to see if it has blocked the optical signal. If it has, tighten the nylon bolt to secure the thermoelectric cooler to the optical amplifier.

4. Make sure that the laser aim has not changed. The tilt motor can sometimes adjust on its own between power up and power down. Also, shock from vehicle dynamics can cause minor tilt motor variations. Verify the tilt motor settings and log this information during calibration.

Laserlux cannot read stripe during slight acceleration or deceleration

The optical alignment may not be set correctly. The rectangular shape of the Laserlux's measurement area is designed to detect the laser from 8 to 12 meters. The Laserlux was designed this way to account for the vehicle dynamics occurring during testing. The following procedure is a useful way of using this design principal to optically align the laser in daylight.

This procedure does not replace the full optical alignment procedure, which should be performed at least once every other month in a darkened environment.

1. Find a flat area that you would consider level enough for a calibration.

2. Place the calibration stripe at the standard 10 meter geometry and aim the laser at the panel.

3. After a measurement has been taken, 3/16 inch spacers will be placed below the front tires. The panel will be repositioned to the 11 meter and a new measurement will be taken. The 11 meter setup simulates the condition of the vehicle during acceleration. If the original problem was loss of data during slight acceleration, the laser should be tested at a geometry greater than the standard 10 meter.

4. Continue to move the calibration panel away from the laser and record the furthest distance that the laser is able to measure. The limit should be no greater than 13 meters.

5. Then, the spacers will be placed below the rear tires with the panel repositioned at 8 meter and another measurement will be taken. This step simulates the effect that braking has on data collection.

6. Use these measurements as a distance range in which the laser can read the calibration source during acceleration and braking. If the measurement geometry is too close or far, there will be a loss of data.

7. Adjust the optical alignment (see optical alignment procedure). Adjustments can only be made to the top and bottom (vertical laser alignment) nuts because this method of alignment does not give left or right alignment information. If the laser measures too close, tighten the top adjustment nut and loosen the bottom. If the laser measures too far away, tighten the bottom nut and loosen the top.

8. Always check alignment using the standard procedure as soon as possible. The procedure outlined above is a temporary fix to avoid losing a day of data collection.

DMI ISSUES

DMI recording erratic speeds

The DMI system relies on pulses received from the vehicle driveshaft using the NiteStar system. If there is a momentary connection problem the Laserlux will record speeds erratically.

1. Secure all computer card connections. These cards may loosen and disconnect when the vehicle hits bumps.

2. Remove the cards and clean their edge connectors.

3. Reinstall the cards carefully to avoid bending them.

4. Secure all connections at the back of the computer. The DMI signal enters the computer through the digital-to-analog (D/A) card. The D/A card has a 50-pin steel connector with 2 clips; one on the top and one on the bottom.

5. Relieve any strain on the cables connected to the back of the computer by neatly bundling the cables and tying them to hold the tension of the cable weight.

DMI will not record chainage

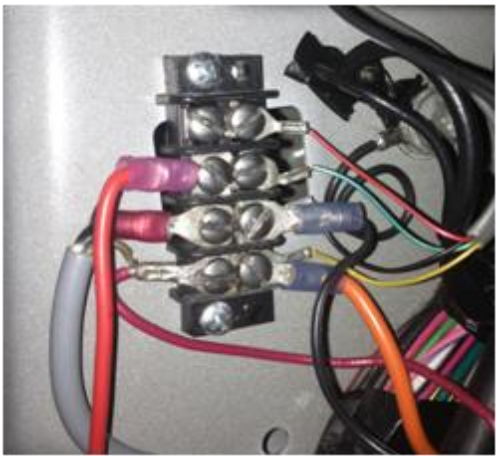
1. Ensure that the DMI has been properly calibrated. After new software installation, it is a very common mistake to forget that the DMI has not been calibrated,

2. Test the DMI to make sure that it operates in simulation mode. If it does software failure can be ruled out as a problem.

3. Test the speedometer to ensure that it is working properly.

4. If none of the previous steps have discovered the problem, the DMI signal will have to be traced through the cables. The vehicle must be moving to find the signal, making this a difficult task.

5. Possibly the power source to the DMI has been disconnected. The power supply line for the DMI will have to be traced to see where a possible short has occurred. Start first at the DMI terminal block located behind the plastic kick panel by the driver side door. The power strip for the DMI is attached to the battery as shown in the photo below.



The terminal block should have 12V DC power to it while the vehicle powered on. If not, this indicates that no power is being sent to the DMI and that the power needs to be traced. If the DMI still does not count the wiring from the auxiliary battery to the driveshaft should be traced.

6. NOTE: If the DMI information is lost during field testing, a quick software fix has been added that allows a user-defined number of pulses to be entered. If this happens, the user can enter the number of pulses from the previous DMI calibration. It is important to log

DMI calibration information for this reason. It is also important to perform a new DMI calibration as soon as possible.

DMI is measuring only one foot per 1000 feet of travel

1. It is likely that new version of the Laserlux software has been installed and the operator has forgotten to calibrate the DMI. Calibration settings may be lost during software installation and must be re-entered. Keep a log of all calibration values before installing software in the field. This record will allow re-entry of calibration values rather than measuring out a DMI calibration site.

2. If this does not solve the issue, refer to previous sections on troubleshooting the DMI.

MAIN POWER SYSTEMS

Inverter shuts down when the Laserlux is on and the van engine is off

Normally, the inverter will shut down and display a low input voltage warning (audible, intermittent beeping) when the van engine is off and the Laserlux is on for more than 10 minutes. There may also be power supply issues from running the thermoelectric cooler off of the inverter. The TEC draws high power (4 amps AC, 120 VAC) off of the inverter and has a high DC current draw from the battery (~50 Amps DC, 12 VDC).

1. Start the van's engine if the Laserlux is going to be used for more than 10 minutes.

2. Check the voltage at both batteries in the vehicle. The second battery may be in the engine compartment, underneath the vehicle along side of the frame, or inside the vehicle in the rear. The voltage should maintain at least 12 volts DC under the load of the Laserlux.

3. If the battery cannot maintain at least 12 volts DC, it should be replaced promptly.

4. If the inverter will not turn on, it is likely that a fuse has blown out between the alternator and the battery. The fuse should be located near the battery in-line with the positive input cable. Keep the inverter off and the van powered down while attempting to check this fuse.

5. Remove the burnt fuse and try to determine a cause for the failure. It is important to make sure that there is not some major electrical problem or short that is causing the fuses to burn out.

6. Replace the fuse with an identically amp-rated fuse.

VIDEO SYSTEM

Alignment camera signal not present at front monitor

1. Secure the cable connecting the laser box to the side of the van. The signal for the alignment camera is not contained in the main data cable, but is in a coaxial cable bundled in with the data cable. This cable is recognized by the BNC terminals on both ends.

2. Make sure the laser switch is on. The alignment camera is dependent on power from the laser switch.

3. Check the BNC connector going into the front monitor.

APPENDIX A: DETAILED DESCRIPTION OF SOFTWARE VERSION V2.2.9.1

As of December 2012 this section is up to date. There have been many software revisions over years. The latest version of the software is a complete revision of the original version. In the following sections is a step-by-step walkthrough of the Laserlux software as of the updating of this manual.

DATA COLLECTION/PROCESSING THEORY

This information is referenced from the original Laserlux 6 User's Manual (Link) provided by Gamma Scientific which can be found at the following location:
G:\NDT\MRU\Operations Manual\Laserlux
Some of the concepts have changed, but nearly all are the same.

Data Collection

Data is collected in 200 evenly spaced, discrete data points along the 1.05 meter (42 inches) path of the laser sweep (scan). Each scan takes place every 0.05 seconds (20 Hz spinning mirror frequency) and lasts approximately 2 milliseconds.

After a specific number of scans (either 1,000 found points or $1/10^{th}$ mile distance) are completed, a file write is entered in the data. Before the data for the next file write is started, the following occurs:

- The laser is turned off and a background scan is performed to calculate a background value.
- The raw A/D values, which range between 0 and 4,096 (represents 0 to 10 volt analog input), are converted to a pseudo retroreflectivity values by multiplying them by the maximum retroreflectivity value (800 mcd/m^2/lux) and dividing the result by 4,096.
- Signal point spikes greater than 50 mcd/m^2/lux are removed by copying the previous legitimate value.

Data Processing

For each scan that is processed and written to a file, the following occurs:

1. The background value is subtracted from the data. The background value is the average (over a scan, done with the laser off) of the sum of the DC offset voltage and the signal attribute to ambient light reflecting off of the pavement, striking the optical sensor.
2. The data is multiplied by the calibration factor obtained during the calibration procedure.
3. Detects and measures peak values of retroreflectance. Peak detection is handled in three similar variants:

a. Two stripes,

b. One stripe, and

c. Calibration

4. Entry points are detected when the R_L exceeds the validity threshold.

5. Exit points are detected when the R_L drops below the validity threshold.

6. The peak is considered to be valid when it contains at least 15 data points (~2.4 inches or ~6 cm) that are above the validity threshold, and does not contain a single data point above the rejection threshold. NOTE: Typically a 3.5 inch (~9 cm) wide stripe is required to return a valid scan. Average peak retroreflectance is calculated for each peak using up to 5 innermost data points on the peak.

7. If more than eight peaks are detected on a single scan, the scan is declared invalid. Peaks can be caused by a variety of roadside objects. These include stripes, rough pavement, gravel, area of spilled glass beads, raised pavement markers, and abnormally high pavement retroreflectivity.

8. If there are no peaks found, the scan is considered invalid.

9. If one or two peaks are found, they are returned to the data handler. One peak only in the case of single lines.

10. All R_L values not belonging to peaks are considered road retroreflectance and are averaged over the scan.

11. For each measured scan within the file write interval, the following is recorded:

    a. Average R_L

    b. Number of valid scans per file write

    c. Average R_L of the left and right stripes in separate columns, as well as a separate column for an average of two centerline stripes.

    d. Number of valid left and right stripe scans. NOTE: Left and right stripes are identified only if both are present in the same scan. If only one stripe is detected, there is no way of determining whether it is a left or right stripe, so by default, single stripes are considered left stripes.

    e. Overall average R_L. This is a composite average. Where single lines are found, the value is incorporated into the station average; where double lines are found, the average of the left and right values are incorporated into the station average. Thus, the reported average retroreflectance may be completely different than the average of the right retroreflectance and the left retroreflectance.

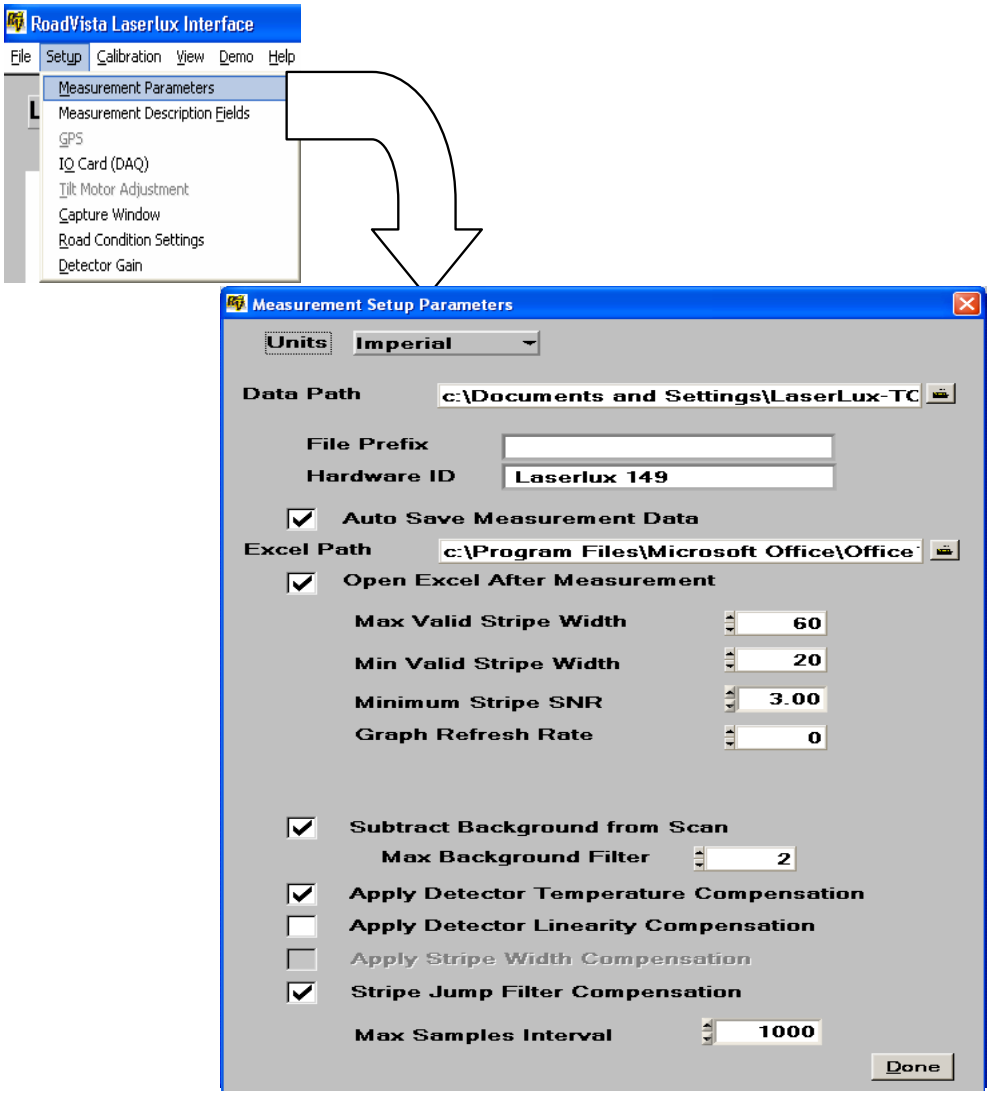
f. Number of scan in which at least one stripe has been detected.

g. At the end of the file write interval, the data handler summarizes the aforementioned data and writes them to an ASCII text file either saved automatically or manually depending on the user-defined settings. In the automatic save mode, the date and time stamp from the computer clock will be added to the file.

LASERLUX SOFTWARE PULL-DOWN MENUS AND OPTIONS

Setup Menu

- Measurement Parameters
  - In this menu are options for the operator to enter that are related to the measurement and output of data.



- Below is a list of parameters and an explanation of each:

  - Unit: Choose either metric or imperial, depending on what type of system you are working with

  - Data Path: This is where all Laserlux output files will be automatically saved. This is a good feature if you accidentally delete a file that you are trying to save somewhere else. The files will always be in this folder as long as the *Auto Save Measurement Data* checkbox is marked.

  - File Prefix: This will be added to the beginning of the file name. It is an optional field, but can be useful for naming convention and organization.

  - Hardware ID: This will be the unit specific ID that was given to each unit by Gamma Scientific. The FDOT currently owns units # 127 and #149.

  - Auto Save Measurement Data: Check this box to save the data to the folder specified in the *Data Path* field.

  - Open Excel After Measurement: This will open the generated Excel spreadsheet after the *Stop Scan* button is pressed. This is useful if you plan to name files differently than the default naming convention.

  - Max Valid Stripe: This tells the software how many data points along the laser sweep path to allow for the maximum width of a stripe. Default is 60 which is about 12.6 inches.

  - Min Valid Stripe: This tells the software how many data points along the laser sweep path to allow for the minimum width of a stripe. Default is 10 which is about 2.1 inches.

  - Peak Width to Calc Avg: This parameter will tell the software how many data points to use in averaging the R_L. Minimum is 1 and maximum is 5. The software uses the peak data point and the suggested points closest to the peak point.

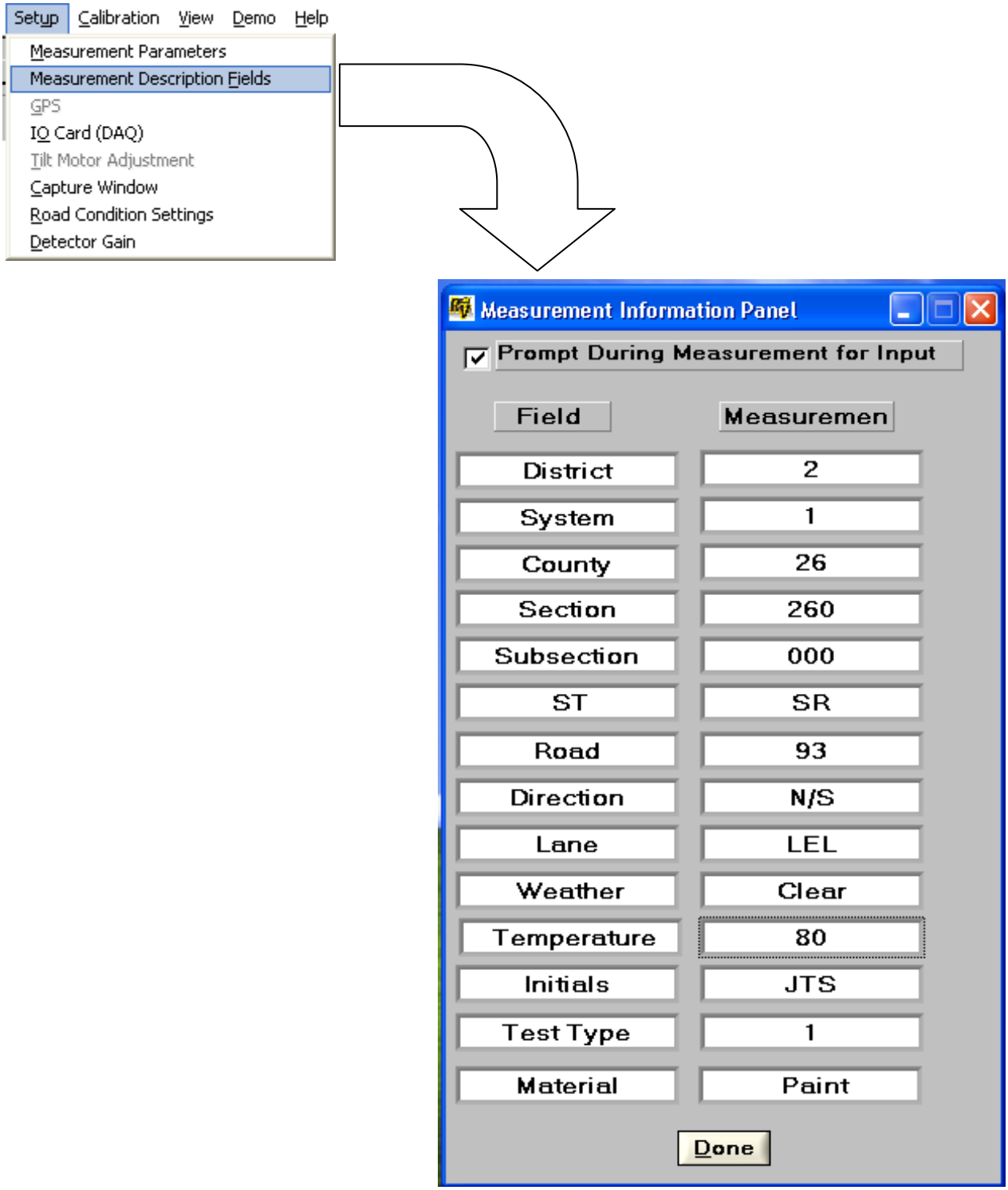
  - Minimum Stripe SNR: This is the signal-to-noise ration from the photodetector amplifier. The value assigned is the multiple of how much greater the value of retroreflection needs to be greater than the background noise in order to be collected. A good value that has been determined for this setting is 3, but it is up to the operator to experiment with different values.

  - Graph Refresh Rate: The fastest setting for this field is zero and the slowest setting is 20. If you are operating on a slower computer, it is recommended to slow down the refresh rate. All points are still collected in the software this just provides the monitor to be updated less often.

- Apply Detector Temperature Compensation: Check this box if you wish to have temperature compensation factors applied to the test data. Only check this if you have already run a stationary creep test and input the temperature compensation factors.

- Apply Detector Linearity Compensation: This checkbox will apply a linearity offset to the scan window readings. If you are noticing extreme measurement drop offs at the edges of the scan window, you may use this setting. As with the temperature compensation, the linearity needs to be quantified and entered into the software before it can be applied.

- Measurement Description Fields
    - This section is for adding information that is test-specific. All of the fields are user-defined, but in the future the *Field* column will be standardized to match the output to the database.



- Field: This section is for the operator to add whatever parameters they would like to be appended to the output file after the test is run. The FDOT has standardized some of the fields in order to streamline data addition to the database.

    - District: Enter the numeric state district code that the test is being performed in.

    - System: Here is where the type of roadway system is entered. The choices are:

        1. Primary
        2. Secondary
        3. Toll/Turnpike
        4. Interstate

    - County: Enter the numeric code for the county that the test is being performed in.

    - Section: Enter the roadway section that is being tested.

    - Subsection: Enter the subsection, if there is one, of the roadway tested. If there is no subsection, input "000".

    - ST: This is the field where you can enter if it is a state route or county route.

    - Road: This is where you enter the route number, in addition to the roadway ID

    - Direction: Enter the direction of travel that the test is being performed in.

    - Lane: Enter the lane that is being evalutated.

    - Weather: Enter environmental conditions (e.g., *Clear* or *Cloudy*) in this field.

    - Temperature: Enter the temperature of the outside environment.

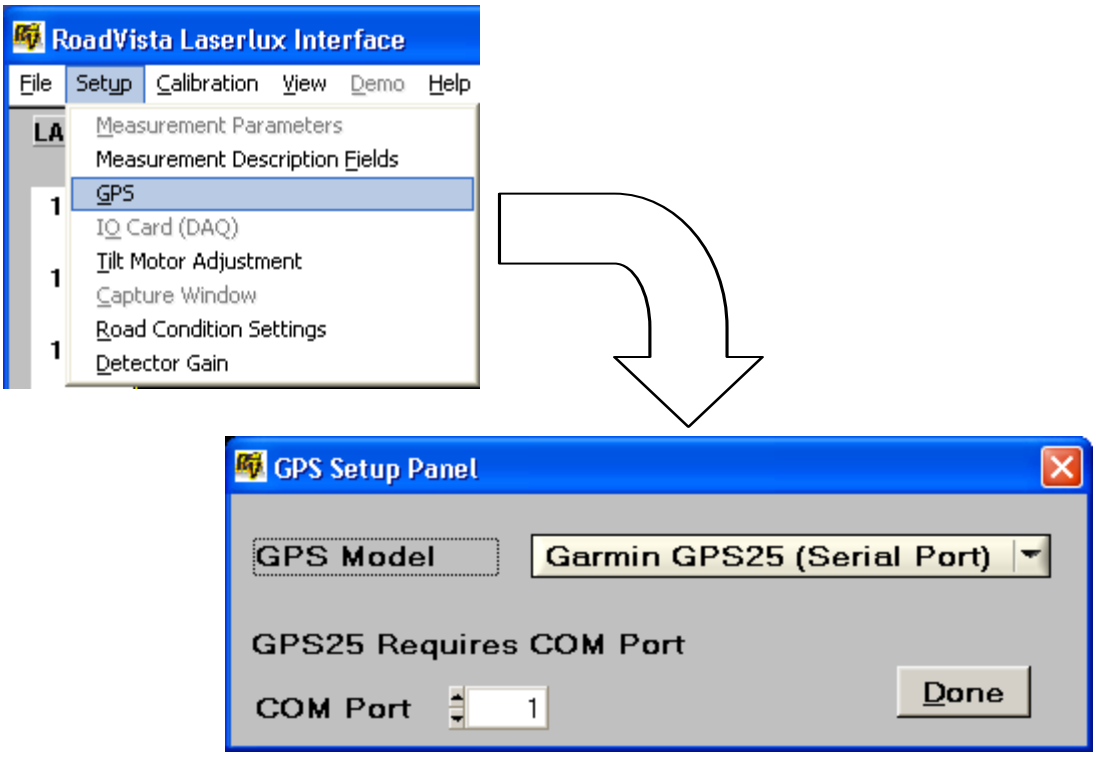
    - Initials: Enter the initials of the Operator(s) that ran the test.

- Test Type: This field denotes the reason for the evaluation.

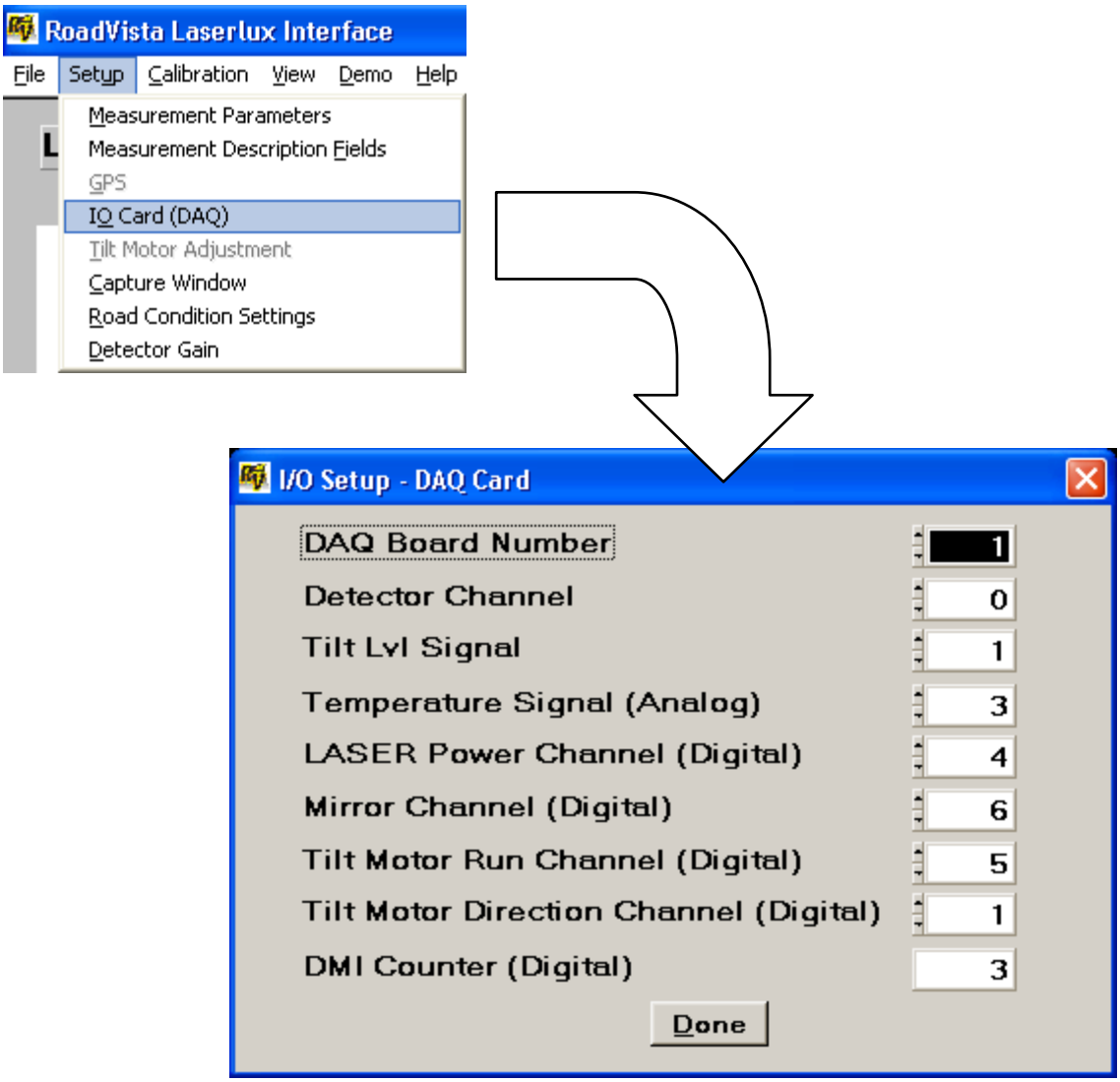
    1. Inventory
    2. New Construction/Overlay
    3. Qualified Products List
    4. Vendor Certification

- Material: Enter the type of material that the markings are made out of. For example; thermoplastic, preformed tape, etc.

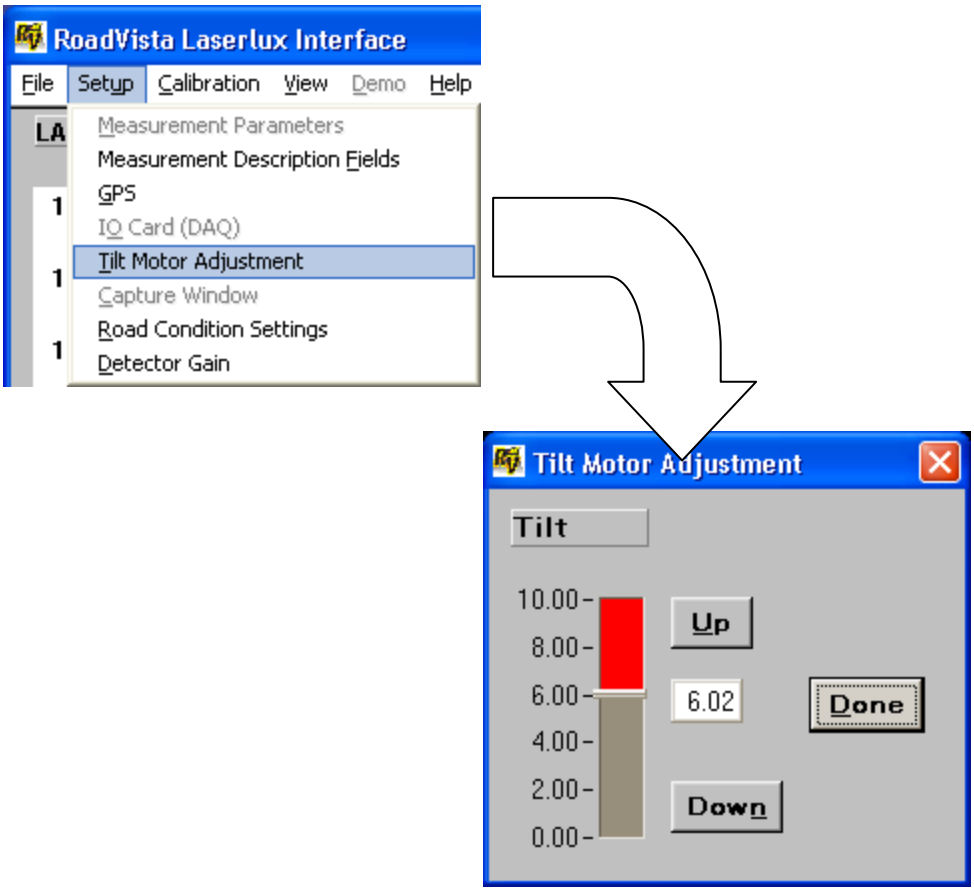
- GPS
    - By accessing the GPS menu, it is possible to change the input of the GPS module to the laptop. The choices are USB or serial port. Also, the settings of the communication port can be adjusted here. If there are problems with getting GPS data to the laptop, the *COM Port* setting may need to be changed to match the settings in the hardware profile of the laptop.



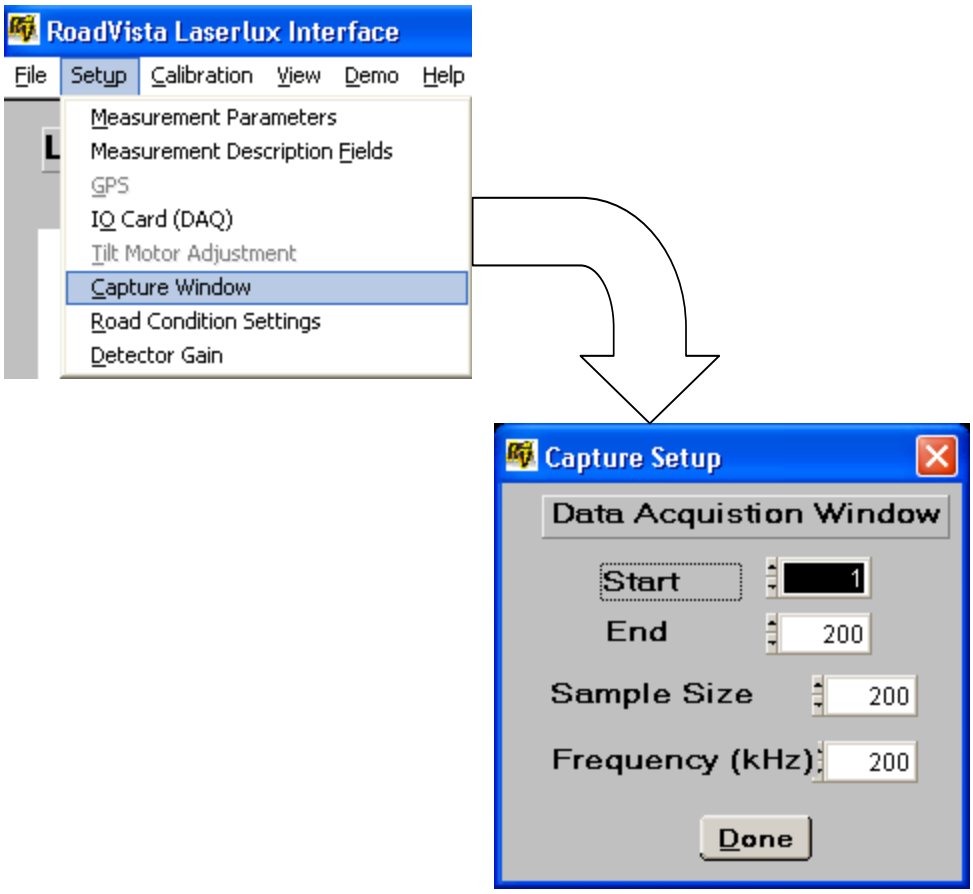
- IO Card (DAQ)
    - This menu will allow the user to control the communication settings between the laptop computer and the Laserlux. This menu is for advanced users and should be left at the default settings unless there are communication problems with the data acquisition software. The numbers associated in the box are the channels in which the Laserlux is transferring information.



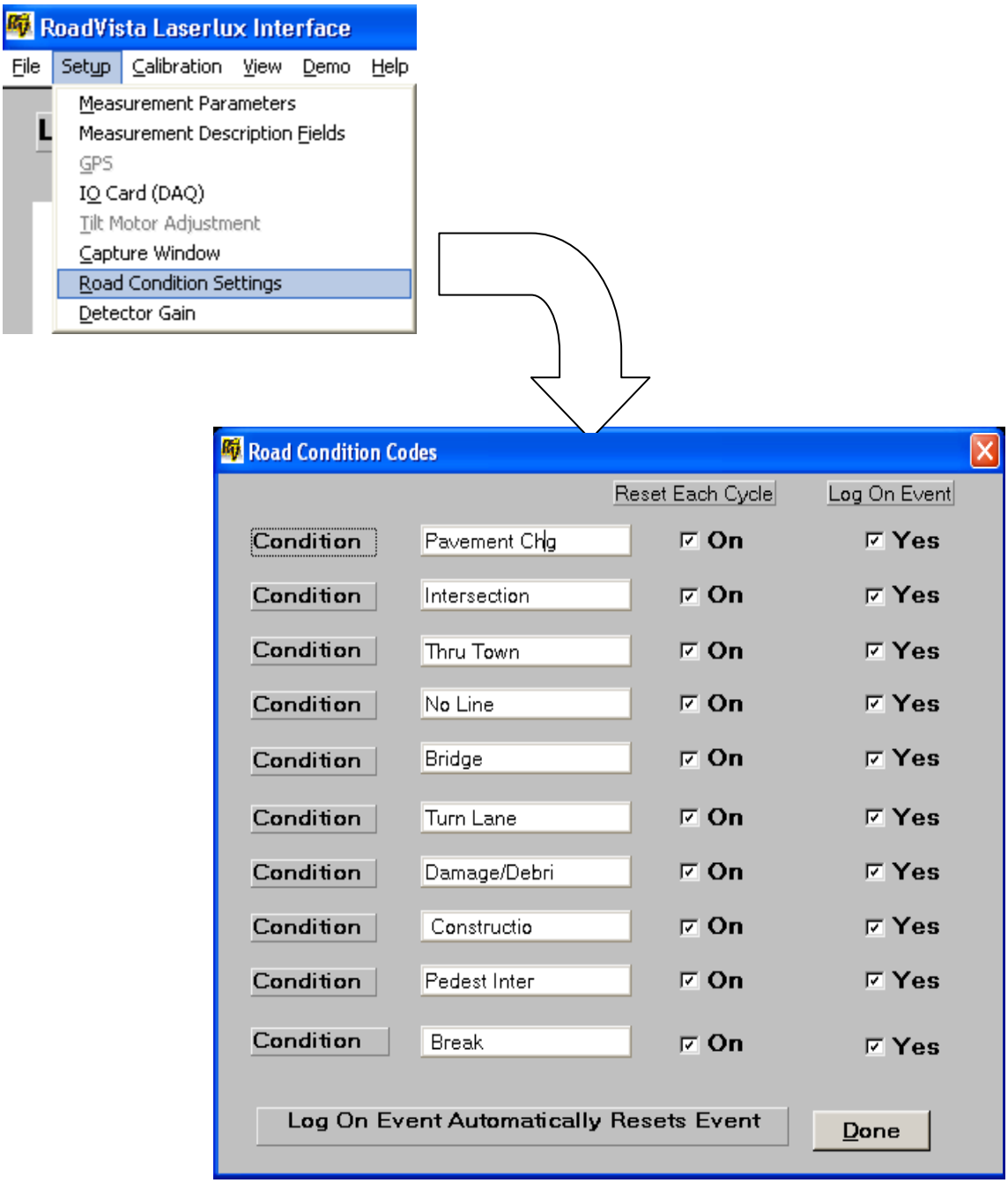
- Tilt Motor Adjustment
    - This option is to adjust the tilt motor located inside the Laserlux unit. This allows the user to manually adjust the angle of the unit from inside the vehicle during calibration. The tilt motor should not be moved while tests are being performed to avoid compromising the data. The minimum setting on the tilt motor is near zero and the maximum setting is 10. The unit should be closest to the 30 meter geometry at a setting of 5. The tilt motor should only be used once the height of the Laserlux platform is set as accurately as possible. It is safe to adjust the angle with the tilt motor based on the 8-to-12 meter geometry measurement range that the Laserlux is capable of.



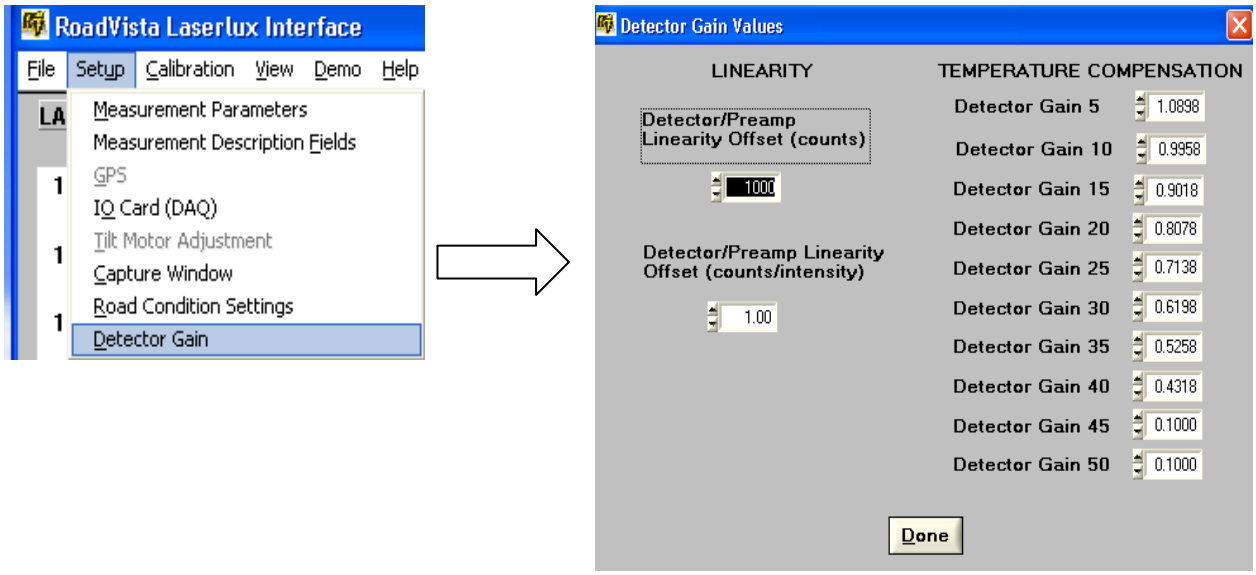
- Capture Window: This menu has options for edge filter settings in the scan window. The *Sample Size* and *Frequency* fields should be left alone. To manually change the start and end points without having to open the *Capture Setup*, just click within the scan window and drag each edge filter to the desired location. The edge filters are a temporary software fix until the scan window drop off is quantified and mitigated through hardware.



- Road Condition Settings
    - This menu will allow user-defined event codes to be added to the interface. The *Reset Each Cycle* and *Log On Event* checkboxes will allow the user to control whether or not they would like the event logged or just to reset the file write cycle when the event key is pressed. It is up to the operator to enter event codes. It is suggested, though, to minimize confusion during data post processing.

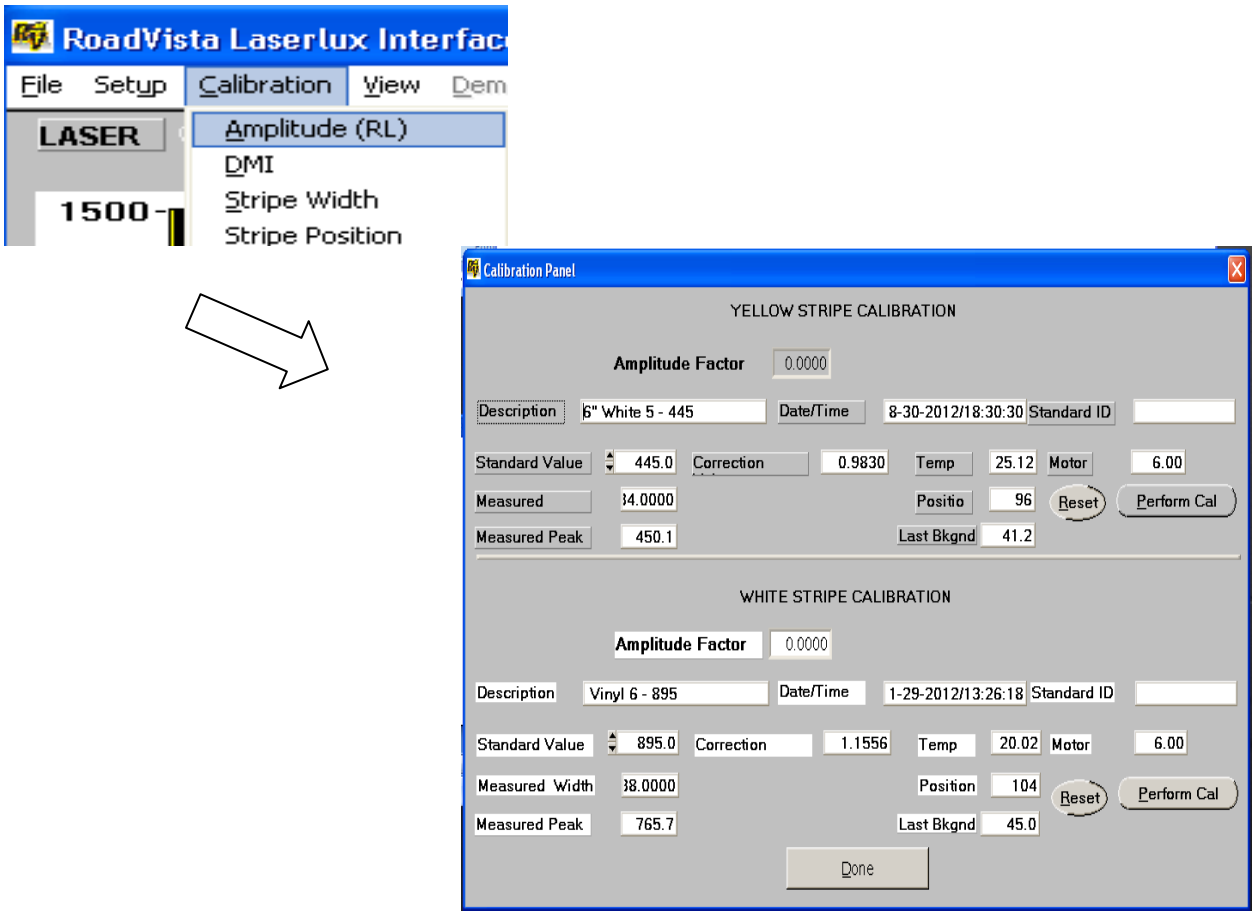


- Detector Gain
    - When applying gain factors for either linearity or temperature, this window allows the operator to make the changes. The linearity is for extreme measurement drop offs at the edge of the scan window. The linearity should be quantified and entered into the software before it can be applied. For Temperature compensation a stationary creep test should be performed to input the factors.

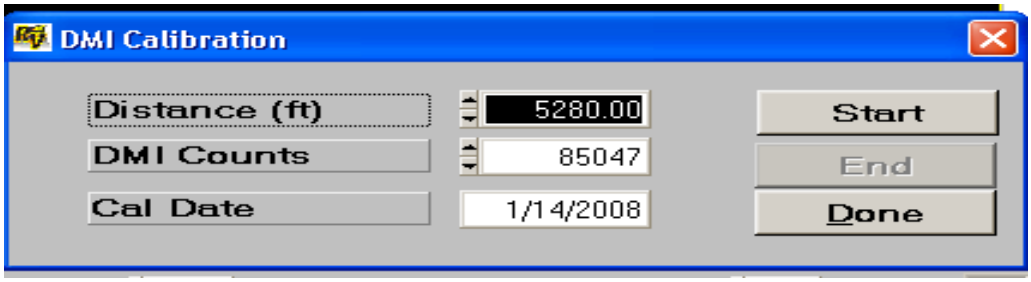


Calibration Menu

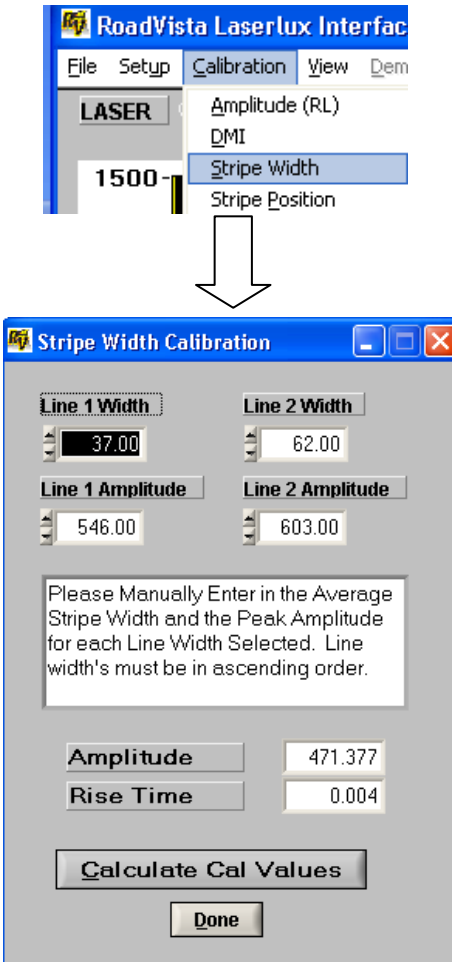
- Amplitude (R_L)
  - The general procedure for calibrating the unit is located in the Equipment Calibration Procedure section. This window allows for the calibration of the R_L value before testing with the unit. The top section is for yellow strips and the lower portion of the window is used for a white calibrated strip. When using a ceramic tile or reflective vinyl sheeting for calibration, any color can be used.



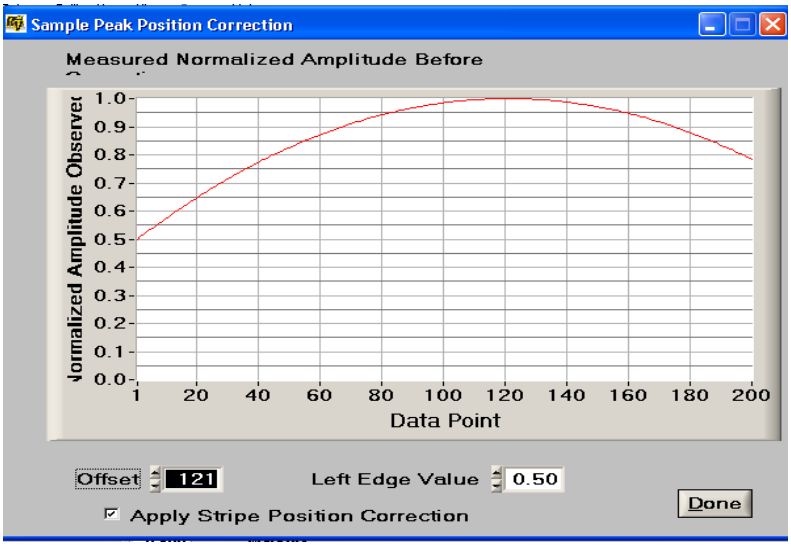
- DMI
    - The general procedure for calibrating the DMI of unit is located in the Equipment Calibration Procedure section. A more detailed explanation is presented. This window provides access to perform the calibration of the DMI.



- Stripe Width
    - The stripe width calibration window allows for the operator to adjust for strip widths.

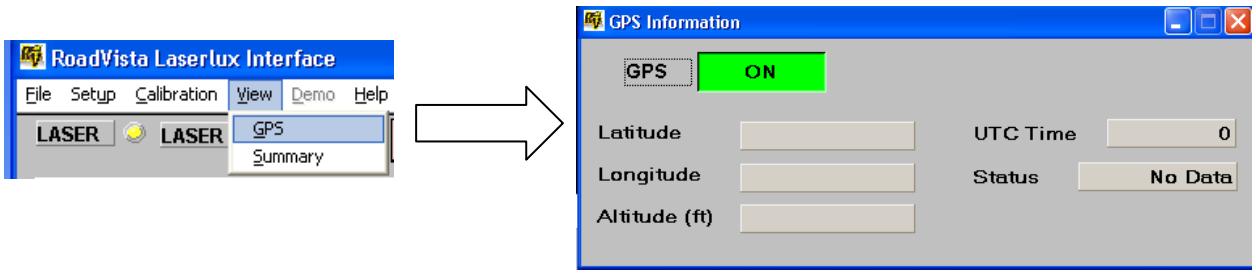


- Stripe Position
    - The strip position allows the operator to view the normalize amplitudes. The left and right offsets must be defined.

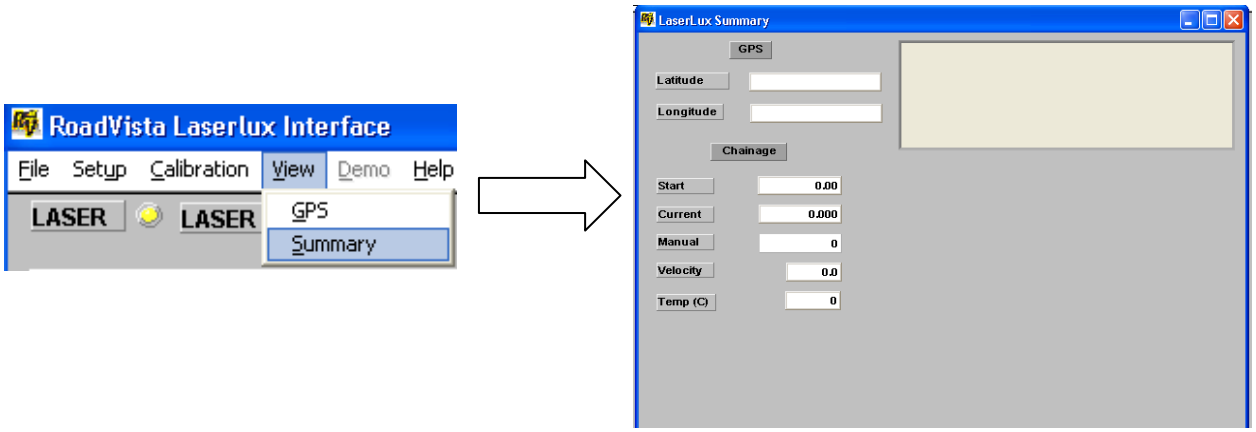


View Menu

- GPS
    - The GPS window displays all of the GPS data. Listed are the coordinates with elevation.

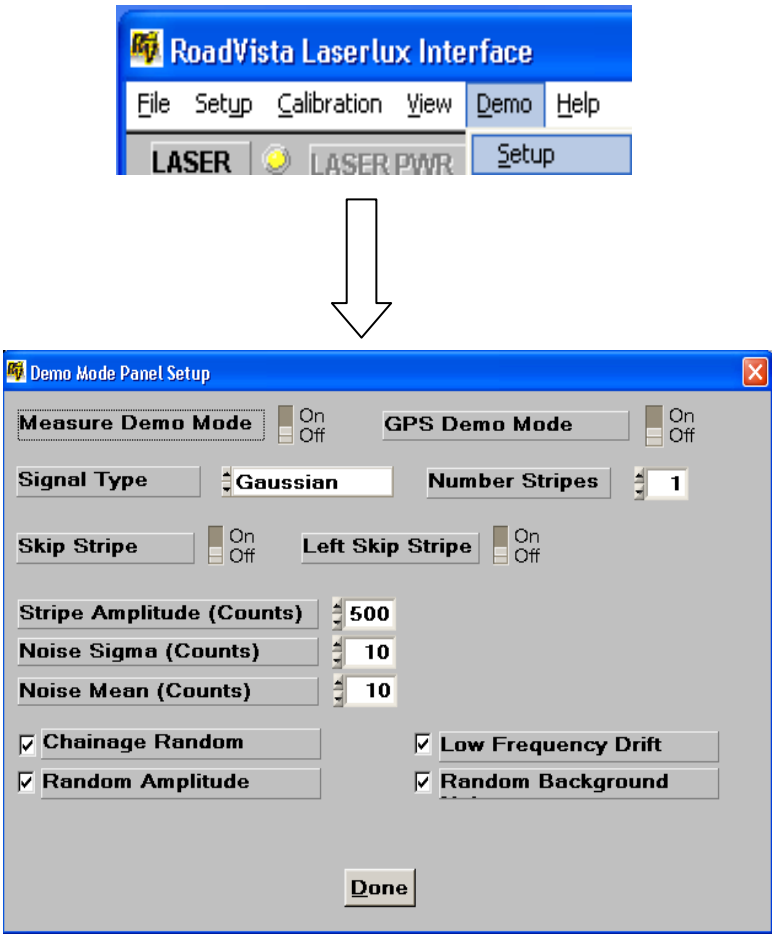


- Summary
    - On the summary tab more detailed GPS data is specified. Also mileage, temperature and speed information is displayed too.



Demo Menu

- Setup
    - For training needs, a demo simulator is programmed within the software. This demo allows operators to get an understanding of the unit during data collection times. This mode is simple to use and very practical for training and familiarity needs during testing.



Help Menu

- Contents – This is a help file used to search various information or topics concerning the system.
- Contacting Roadvista – Address information to reach Roadvista at:

RoadVista
8581 Aero Drive
San Diego, CA 92123
Phone: (858) 279-8034
Fax: (858) 576-9286
www.roadvista.com

- About – summarizes license information.

COMPENSATION VARIABLE PROCEDURES

Temperature Compensation

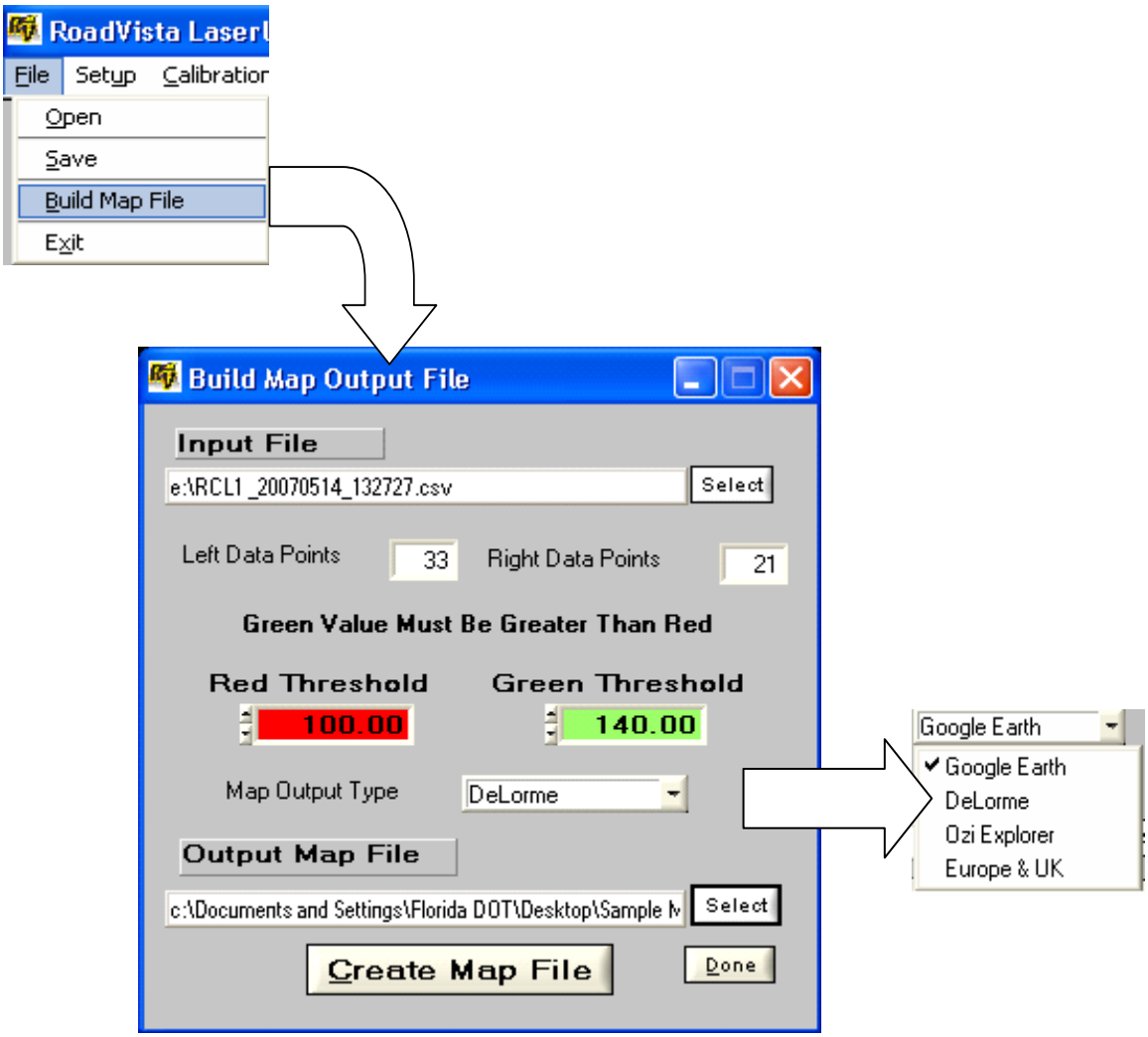
- The temperature compensation test can be performed by a controlled temperature change to the Laserlux while collecting data from a known calibration standard.
    1. Perform a stationary creep test with the Laserlux by adjusting the thermoelectric cooler to 10°C with the Laserlux turned off.
    2. Once the thermoelectric cooler reaches a stable temperature, turn the Laserlux on and begin warm up period for the laser and internal components.
    3. With the Laserlux warmed up and at 30 meter geometry with the calibration standard, calibrate the software.
    4. Once the calibration if complete start the stationary creep test.
    5. Make sure the software collects one write or cycle before adjusting the thermoelectric cooler in incremental steps to avoid condensation.
    6. When the software temperature reaches 25°C the thermoelectric cooler can be turned off and allow the laser to increase the temperature in the box.
    7. Once the temperature inside the box becomes stable at a maximum temperature, stop the scan and save the data.
    8. The data can be graphed as temperature versus retroreflectivity.
    9. Obtain a line to average the data.
    10. Set the Detector Gain 25 box equal to 1.0000 and adjust the following Detector Gain boxes accordingly depending on the graph.

Stripe Position Correction

- The stripe position correction allows the operator to view the normalize amplitudes.
    1. First the Laserlux needs to be setup using 30 meter geometry with a known calibration standard.
    2. With Laserlux warmed up and calibrated, start the scan with the calibration standard in the center of the software window.
    3. Allow the average to stable and record the retroreflective reading of the calibration standard.
    4. Move the calibration standard to the left extremity of the software window still allowing an accurate reading for the standard.
    5. Start the scan and once the average appears stable, obtain the reading for the calibration standard on the left extremity of the software.
    6. The Left Edge Value can be obtain by taking the average at the left edge and dividing the average at the center.
    7. The offset is the position in the software in which the peak of the parabolic profile occurs.

BUILDING MAP FILES

When collecting retroreflectivity data, it may be necessary to display a map of the roadway tested with the results. To do this, you may build a map file of the data. When a map file is built, a simple text file is written that contains GPS coordinates of each data point. These coordinates with corresponding R_L values will be overlaid onto a map of the roadway. To build a map file from the Laserlux software, go to the File menu and select *Build Map File*. See the following figure for a schematic of the menu options. When choosing the map output type, make sure that whichever is chosen is the type of mapping software installed.



SOFTWARE UPDATES FROM THE GAMMA SCIENTIFIC FTP SITE

Periodically, there will be posted updates of the Laserlux software. Gamma Scientific has a File Transfer Protocol (FTP) site that they maintain for data transfer of sensitive information or files that are too large to send through email.

APPENDIX B: PHYSICAL DESCRIPTION OF LASERLUX

LASERLUX GEOMETRY

The Laserlux operates on the principal of 1/3 of the CEN prescribed 30-meter geometry. This means that all of the geometry is maintained, but the distance that the Laserlux is measuring is set at 10 meters. This geometry setup is equivalent to an average passenger car driver viewing 30 meters ahead of the vehicle. The observation angle (angle between light out and light in) of the Laserlux is 1.05° and the co-entrance angle is 1.24°.These angles conform to the specifications set forth in EN 1446 and ASTM 4061. The Laserlux uses a 10 mW helium-neon laser to simulate headlight illumination and retroreflectance. The retroreflected laser light is passed through two narrow band pass filters (filter out ambient light) and received by a solid-state photodiode. See the figure below for a schematic of the MRU geometry.

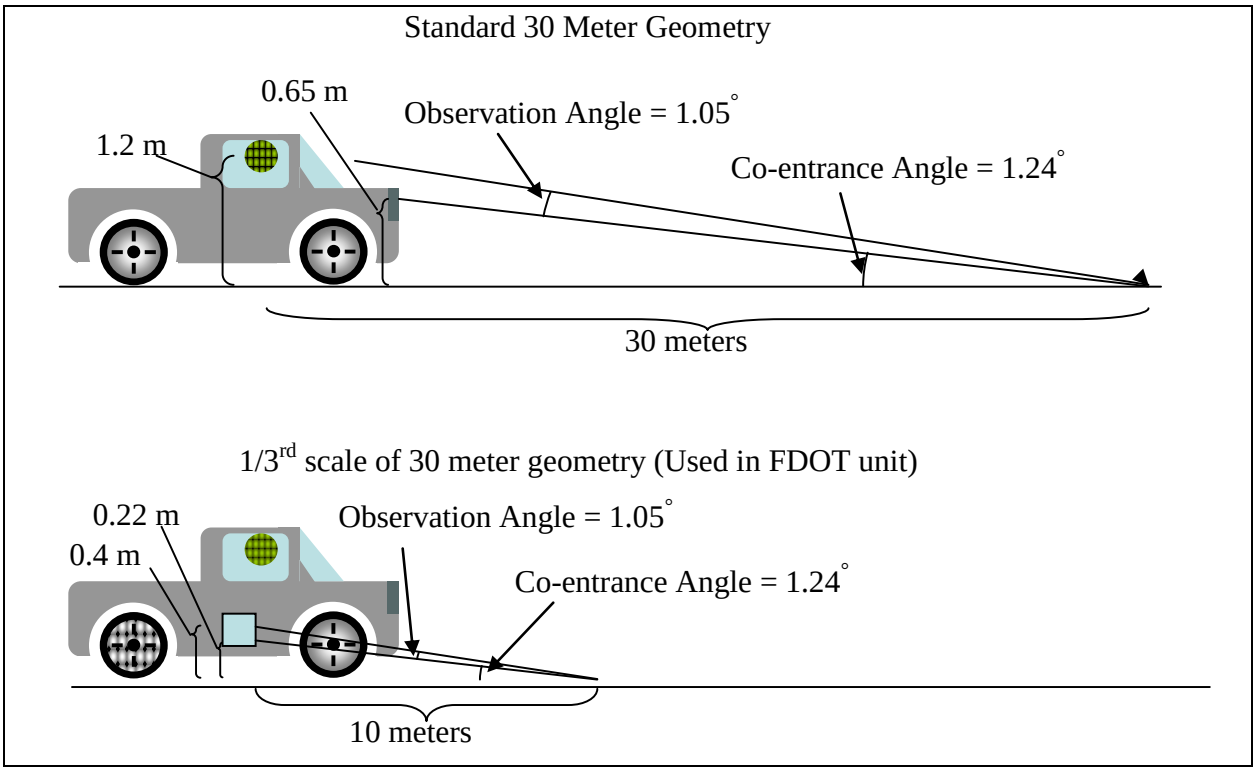


Figure 14 - 30 Meter Geometry

Figure 15 – Measurements for Geometry

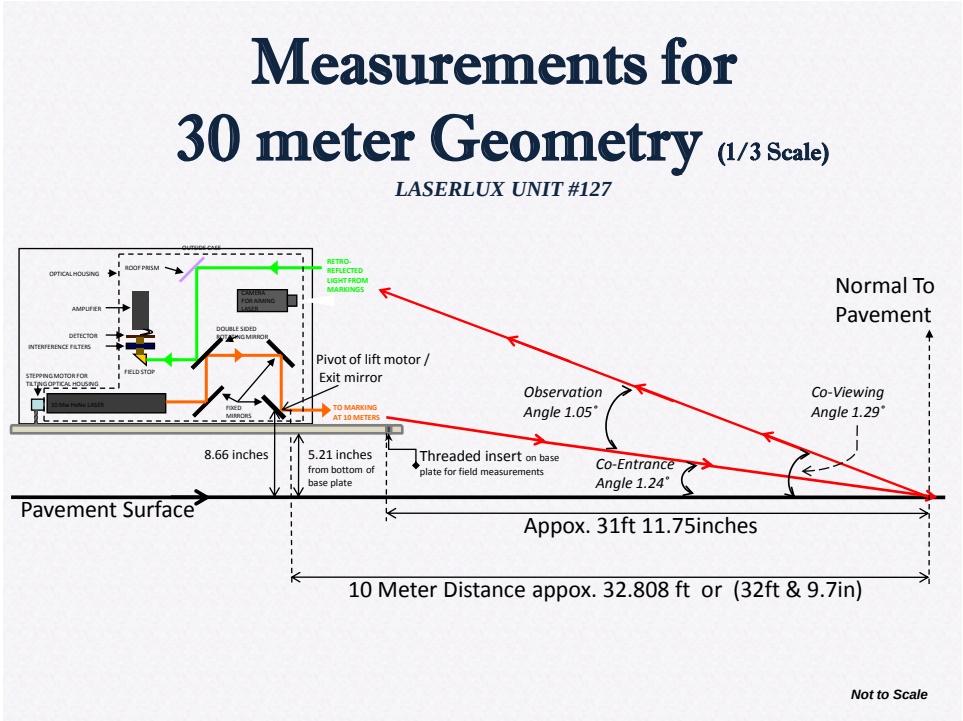


Figure 16 - CEN 30 Meter Geometry

OPTICAL COMPONENTS

The Laserlux has a complex array of optical equipment inside that allows the manipulation of the laser light going out and being received. A detailed discussion of the physics and mechanics of the internal workings of the Laserlux is beyond the scope of this manual, but a schematic is provided in the figure below for reference.

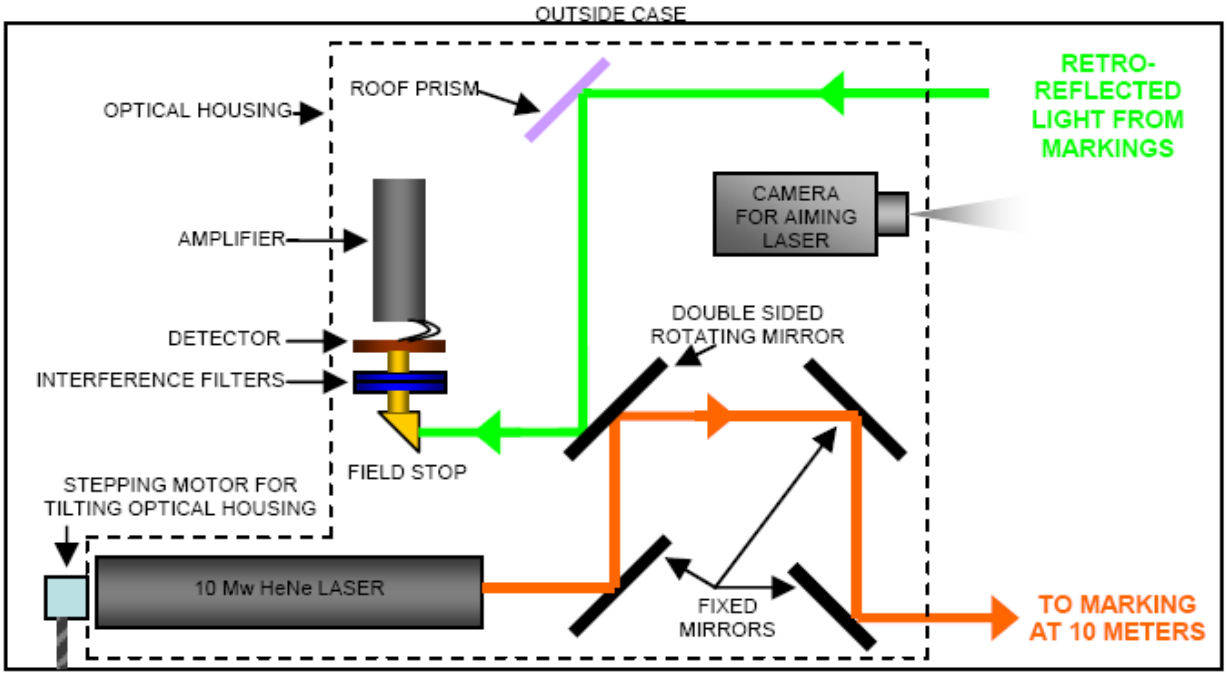


Figure 17 - Laserlux Schematic of the Optical Path

APPENDIX C: RETROREFLECTIVITY EXAMPLE DATA

ORIGINAL OUTPUT FILE

When a test is completed and the *Stop Scan* button is pressed, an Excel file is generated and saved to the user-defined directory if the checkbox *Auto Save Measurement Data* is checked. If the *Open Excel After Measurement* box is checked, the generated spreadsheet will open automatically.

_20120815_1426	(Road Vista: 2.3)																												
Florida Dept. of T	(LL 127)																												
Description																													
Hardware ID	Laserlux 149																												
Imperial Units &	0.1																												
White Stripe Cali	1.1121	8-15-2012/	Calibratio	Vinyl 6 - 895	895	26.59	46.9																						
Yellow Stripe Cal	1.2386	8-6-2012/1	Calibratio	6" White 2 - 9(	921	25.03	41.5																						
Detector Comper	Yes																												
Stripe Width Com	No																												
Measurement Date																													
Acquisition Wind	1																												
Acquisition Wind	200																												
District	5																												
System	1																												
County	79																												
Section	220																												
Subsection	0																												
ST	SR																												
Road	430																												
Direction	E/W																												
Lane	RCL																												
Weather	SUNNY																												
Temperature	95																												
Initials	FAO																												
Test Type	2																												
Material	Thermo																												
Chainage	Manual Stripe Typ	Left Point	Left Peak Max	Left Peak Min	Left Peak Av	Left Peak St	Left Con	Right Point	Right Peak Max	Right Peak Min	Right Peak Av	Right Peak St	Right Con	Two-Stripe Av	Computer UTC Time	Longitude	Latitude	Altitude	GPS Fix	Temp	Average Speed	Background	Event Codes						
0	0 Start	0	0	0	0	0	0	0	0	0	0	0	0	0	14:26:46	0.000000°	0.000000°	0	Unusua	26.37	0	0							
0.1	0 Left Solid/	164	694.56	111.13	208.78	86.82	0.52	139	315.89	140.46	210.54	38.26	0.54	209.66	14:26:59	0.000000°	0.000000°	0	Unusua	25.92	7	128.2							
0.201	0 Left Solid/	92	796.77	125.83	219.67	87.69	0.53	63	315.07	168.15	224.6	27.48	0.51	222.13	14:27:10	0.000000°	0.000000°	0	Unusua	26.06	7	70.2							
0.302	0 Left Solid/	199	1011.23	141.26	225.75	85.42	0.53	183	359.11	134.78	232.92	43.58	0.52	229.33	14:27:42	0.000000°	0.000000°	0	Unusua	26.23	7	52.4							
0.403	0 Left Solid/	152	739.55	88.27	218.21	71.86	0.52	140	778.6	170.16	231.37	76.39	0.53	224.79	14:27:57	0.000000°	0.000000°	0	Unusua	26.41	7	175.3							
0.505	0 Left Solid/	167	758.78	169.74	223.26	60.9	0.52	147	530.36	186.98	235.09	41.55	0.52	229.18	14:28:11	0.000000°	0.000000°	0	Unusua	26.41	7	71.6							
0.606	0 Left Solid/	209	769.45	155.71	275.65	95.17	0.49	169	730.55	196.1	284.75	65.35	0.48	280.2	14:28:27	0.000000°	0.000000°	0	Unusua	26.28	7	95.1							
0.707	0 Left Solid/	230	1257.6	163.57	248.43	98.89	0.45	207	325.81	176.74	250.99	32.29	0.46	249.71	14:28:43	0.000000°	0.000000°	0	Unusua	26.06	7	92.5							
0.809	0 Left Solid/	212	1298.04	108.34	242.86	118.84	0.47	157	544.98	121.74	235.96	45.3	0.45	239.41	14:29:19	0.000000°	0.000000°	0	Unusua	26.01	7	85.4							
0.899	0 Edge Line	112	678.21	171.96	271.33	69.39	0.52	190	656.82	148.99	268.25	64.38	0.52	269.79	14:29:31	0.000000°	0.000000°	0	Unusua	26.1	7	84							
0.909	0 Edge Line	9	284.63	210.43	243.03	25.73	0.49	24	289.89	215.92	244.93	19.29	0.51	243.98	14:29:32	0.000000°	0.000000°	0	Unusua	26.06	7	81							
1.011	0 Left Solid/	99	326.43	170.38	235.59	25.38	0.5	43	369.18	133.43	241.99	43.17	0.5	238.79	14:29:45	0.000000°	0.000000°	0	Unusua	26.41	7	93.8							
1.112	0 Left Solid/	231	786.06	188.55	266.07	72.27	0.45	181	521.58	214.78	281.76	45.52	0.46	273.91	14:29:59	0.000000°	0.000000°	0	Unusua	26.32	7	98.5							
1.213	0 Left Solid/	180	1276.79	201.26	265.79	105.54	0.45	145	807.57	216.95	274.92	75.49	0.45	270.35	14:30:11	0.000000°	0.000000°	0	Unusua	26.32	7	99.2							
1.313	0 Left Solid/	179	303.67	174.81	241.38	25.09	0.45	160	302.67	179.49	252.56	25	0.45	246.97	14:30:22	0.000000°	0.000000°	0	Unusua	26.28	7	79							
1.414	0 Left Solid/	202	708.71	143.29	236.3	65.42	0.53	194	669.82	180.29	240.53	39.72	0.53	238.41	14:30:34	0.000000°	0.000000°	0	Unusua	26.32	7	70.9							
1.517	0 Left Solid/	131	773.11	173.5	246.84	79.01	0.55	117	754.49	164.68	237.03	64.35	0.53	238.93	14:30:45	0.000000°	0.000000°	0	Unusua	25.92	7	74.4							
1.619	0 Left Solid/	172	774.51	163.37	238.71	83.35	0.5	161	794.14	176.51	253.06	87.32	0.5	245.88	14:30:57	0.000000°	0.000000°	0	Unusua	25.88	7	69.6							
1.72	0 Left Solid/	214	858.56	120.45	221.73	70.87	0.5	198	868.21	128.85	229.43	54.02	0.51	225.58	14:31:12	0.000000°	0.000000°	0	Unusua	26.19	7	61.9							
1.822	0 Left Solid/	197	764.07	141.65	207.27	56.1	0.5	164	764.85	172.33	230.99	62.68	0.52	219.13	14:31:24	0.000000°	0.000000°	0	Unusua	26.06	7	59.6							
1.924	0 Left Solid/	160	677.32	144.63	241.13	63.83	0.52	141	793.12	149.17	248.61	78.52	0.53	244.87	14:31:39	0.000000°	0.000000°	0	Unusua	26.37	7	78.2							
1.967	0 Single Skip	19	738.61	177.74	557.49	149.09	0.82	0	0	0	0	0	0	557.49	14:31:46	0.000000°	0.000000°	0	Unusua	26.41	7	59.1	(1) Pavemen						

The generated spreadsheet should conform to the format described in *FDOT Form# 675-060-15* which can be found at:
G:\NDT\MRU\MRU Statewide Contract\Final (link)
or
http://procnet.co.dot.state.fl.us/forms/byofficedetail.asp?formnumber=675-060-15.
If it does not conform to the format described, FDOT will not expect it.

Once this data is collected, it will be beneficial to plot the R_L trends versus another variable, such as time or chainage. For lab tests, you will want to plot versus time and for field testing you will want to plot versus chainage. In the next section is the Visual Basic code that is used for the preliminary Macro. The Macro will grab columns that are needed from multiple files of the same roadway, import and summarize them into a separate Excel spreadsheet called a Summary Output. This will speed up the process, as well as allow the user to extract data without taking the chance of altering the original data file.

EXCEL MACRO

The following preliminary macro was written for Microsoft Excel summarized the different pavement markings from the same roadway into one Excel spreadsheet which is called a Summary Output. It was made to quickly import data into a database without having to upload individual test files. The *RCI Prelim Macro 4.30.09* (Link) can be found at: G:\NDT\MRU\Production

								MP	MP									Retroreflectivi
District	System	Test Date	County	Section ID	Subsection ID	ST	Road	Begining	Ending	Direction	LEL	L5SL	L4SL	L3SL	L2SL	L1SL	LCL
2	4	05/01/2008	26	260	000	SR	93	0.000	0.100	N/S	266				177	168	205
2	4	05/01/2008	26	260	000	SR	93	0.100	0.200	N/S	318				165	138	214
2	4	05/01/2008	26	260	000	SR	93	0.200	0.300	N/S	411				145	150	199
2	4	05/01/2008	26	260	000	SR	93	0.300	0.400	N/S	364				106	173	237
2	4	05/01/2008	26	260	000	SR	93	0.400	0.500	N/S	228				185	142	215
2	4	05/01/2008	26	260	000	SR	93	0.500	0.600	N/S	241				166	158	226
2	4	05/01/2008	26	260	000	SR	93	0.600	0.700	N/S	417				176		208
2	4	05/01/2008	26	260	000	SR	93	0.700	0.800	N/S	369				228	173	257
2	4	05/01/2008	26	260	000	SR	93	0.800	0.900	N/S	300				163	187	245
2	4	05/01/2008	26	260	000	SR	93	0.900	1.000	N/S	336				153	183	255
2	4	05/01/2008	26	260	000	SR	93	1.000	1.100	N/S	309				198	189	217

y (mcd/m^2/lux)																Material				RCI
RCL	R1SL	R2SL	R3SL	R4SL	R5SL	REL	Weather	Temp	Initials	Vechicle Unit	Test Type	Test	Speed	FIN	Surface	EL	SL	CL	Manu	AADT
							Clear	80	JTS	(LL 127)	1	39	70		FC5	Thermo	Tape	Thermo		48,500
330	99	177				152	Clear	80	JTS	(LL 127)	1	59	70		FC5	Thermo	Tape	Thermo		48,500
315	182	155				136	Clear	80	JTS	(LL 127)	1	60	70		FC5	Thermo	Tape	Thermo		48,500
182	222	155				174	Clear	80	JTS	(LL 127)	1	60	70		FC5	Thermo	Tape	Thermo		48,500
317	182	178				268	Clear	80	JTS	(LL 127)	1	59	70		FC5	Thermo	Tape	Thermo		48,500
288	181	186				202	Clear	80	JTS	(LL 127)	1	59	70		FC5	Thermo	Tape	Thermo		48,500
329	166	150				116	Clear	80	JTS	(LL 127)	1	60	70		FC5	Thermo	Tape	Thermo		48,500
360	163	214				103	Clear	80	JTS	(LL 127)	1	60	70		FC5	Thermo	Tape	Thermo		48,500
340	219	121				280	Clear	80	JTS	(LL 127)	1	60	70		FC5	Thermo	Tape	Thermo		48,500
334	214	142				152	Clear	80	JTS	(LL 127)	1	59	70		FC5	Thermo	Tape	Thermo		48,500
284	170	141				163	Clear	80	JTS	(LL 127)	1	60	70		FC5	Thermo	Tape	Thermo		59,092

SAMPLE DATA PLOTS

The following figure is an example of a plot that shows temperature versus time and R_L versus time. This is the plot from a Stationary Creep Test that was performed during one of the Gamma Scientific maintenance visit.

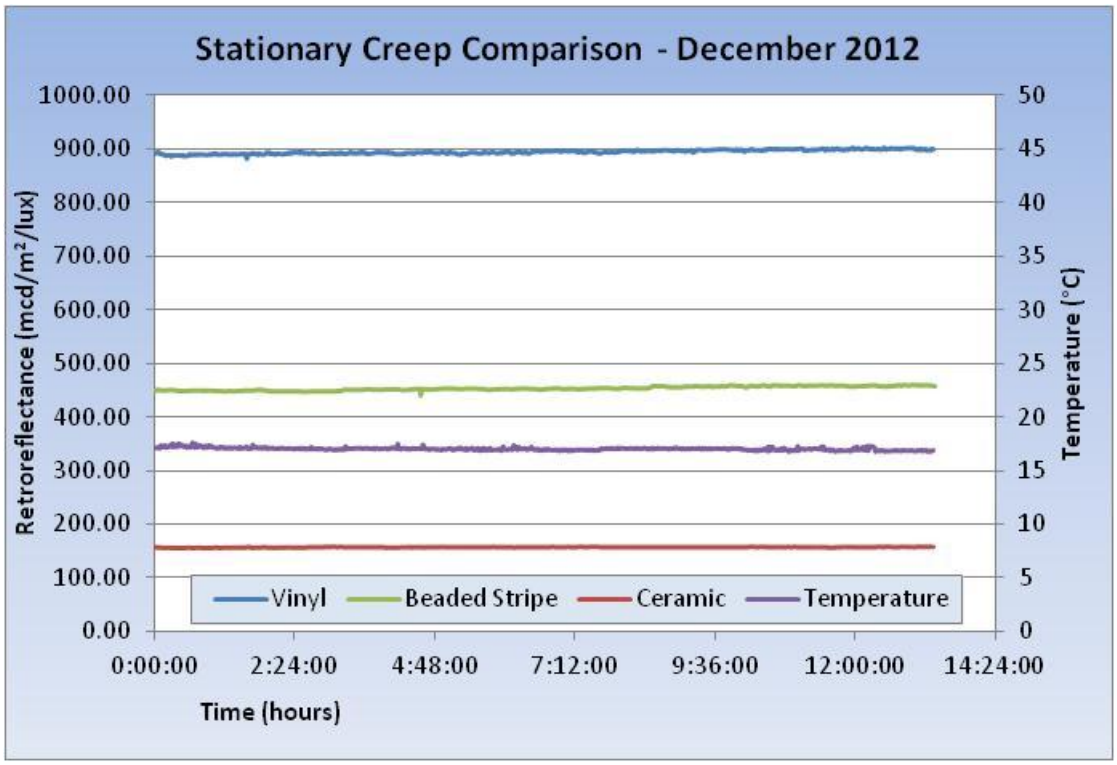


Figure 18 - Lab Test Example Plot

The next figure is an example of a field testing plot. This plot contains R_L versus chainage, but for three measurements of the same stripe with two different MRUs.

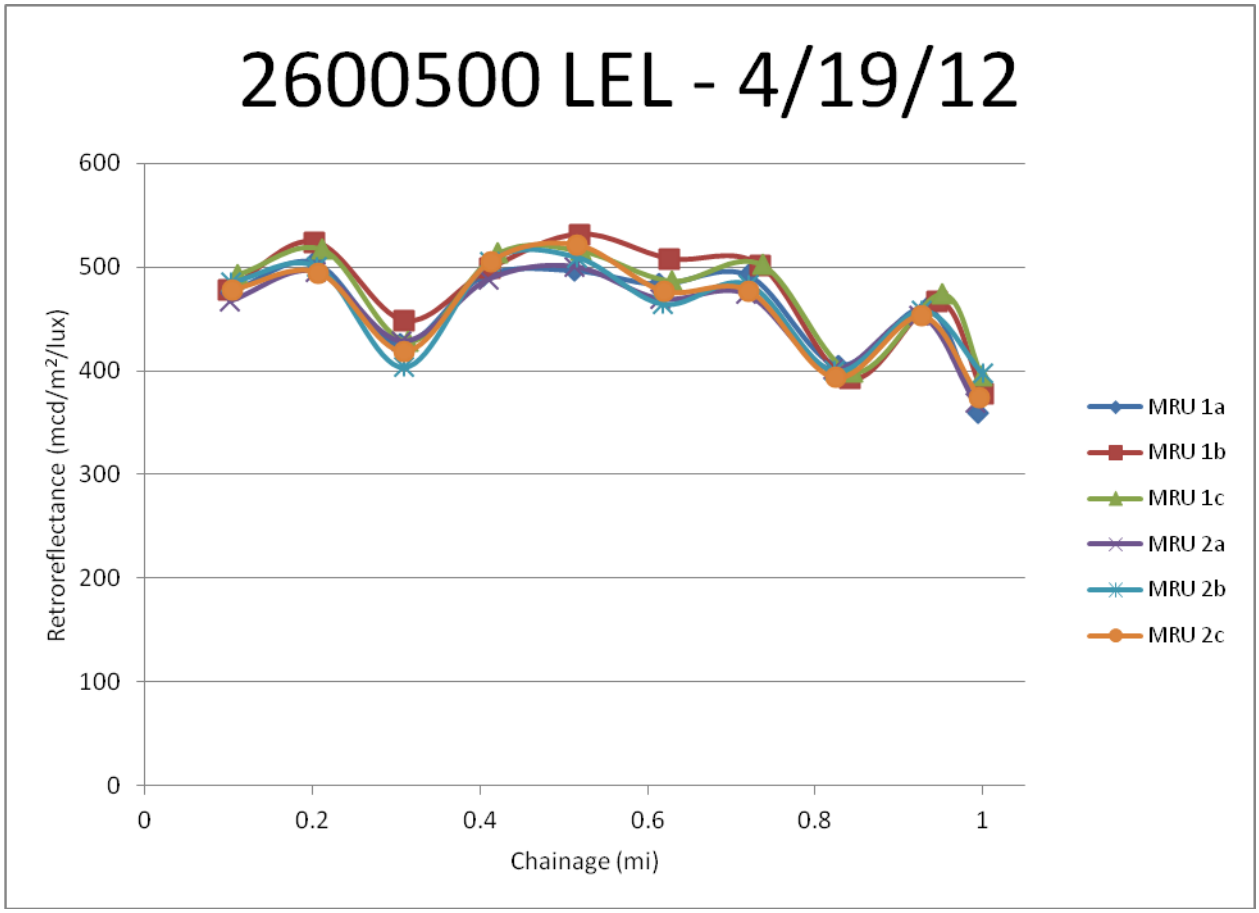


Figure 19 - Field Test Example Plot

APPENDIX D: OPERATOR MAINTENANCE CHECKLISTS

The following three checklists are here for operator reference. The start testing and end testing checklists should be performed each day of testing. The Monthly Maintenance checklist should be performed at least once per month.

PRE-TEST CHECKLIST

- ○ Check computer connections
- ○ Check tire pressure – if air added recalibrate DMI
- ○ Mount Laserlux and brackets to vehicle – preliminary height check - tighten
- ○ Inspect cable ends and connect from van to Laserlux
- ○ Turn on van
- ○ Turn inverter power on and turn Laserlux power distribution box on
- ○ Initialize Laserlux hardware to allow laser to warm up
- ○ While laser is warming up, drive vehicle around to warm up suspension
- ○ Prepare logbook and SLD for testing

POST-TEST CHECKLIST

- ○ Update logbook
- ○ Save Files to computer and flash drive
- ○ Turn off computer
- ○ Turn off inverter and distribution enclosure (two switches and key)
- ○ Remove Laserlux and brackets
- ○ Store cables and Laserlux
- ○ Rinse off vehicle to remove bugs and dirt

MONTHLY MAINTENANCE CHECKLIST

- ○ Laser alignment
- ○ Interference filter check

- ○ Check desiccant
- ○ Check Lexan panel for need of replacement
- ○ Perform scan width test
- ○ Perform 8 to 12 meter geometry test
- ○ Verify calibration standards and log new values if changed

APPENDIX E: RELEVANT SPECIFICATIONS AND STANDARDS

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

Retroreflection Specifications

- D6359 – 99: *Standard Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments*
- E1710 – 05: *Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN- Prescribed Geometry Using a Portable Retroreflectometer*
- E2177 – 01: *Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness*
- E2175 – 01: *Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Continuous Wetting*
- E808 – 01: *Standard Practice for Describing Retroreflection*
- E284 – 06a: *Standard Terminology of Appearance*
- D4061 – 94: *Standard Test Method for Retroreflectance of Horizontal Coatings*

Pavement Marking Material Specifications

- D2369 – 04: *Standard Test Method for Volatile Content of Coatings*
- D1214 – 04: *Standard Test Method for Sieve Analysis of Glass Spheres*
- D1155 – 03: *Standard Test Method for Roundness of Glass Spheres*
- D92 – 05a: *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*
- D256-06: *Standard Test Method for Determining the Izod Pendulum Impact Resistance of Plastics*
- D2240 – 05: *Standard Test Method for Rubber Property – Durometer Hardness*
- D36 – 95: *Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)*
- D570 – 98: *Standard Test Method for Water Absorption of Plastics*

- D1210 – 05: *Standard Test method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage*

- D562 – 01: *Standard Test Method for Consistency of Paints Measuring Krebs Unit (KU) Viscosity Using a Stormer-Type Viscometer*

- D1475 – 98: *Standard Test Method for Density of Liquid Coatings, Inks, and Related Products*

- D3960 – 05: *Standard Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings*

- D476 – 00: *Standard Classification for Dry Pigmentary Titanium Dioxide Products*

- D3723 – 05: *Standard Test Method for Pigment Content of Water-Emulsion Paints by Low-Temperature Ashing*

- D6628 – 03: *Standard Specification for Color of Pavement Marking Materials*

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

- M247 – 05: *Standard Specification for Glass Beads Used in Traffic Paints*

- T250 – 05: *Standard Method to Test for Thermoplastic Traffic Line Material*

FLORIDA METHOD

- 5-541: *Florida Method of Test for Traffic Marking Field Test*

- 5-579: *Florida Method of Test for Traffic Striping Retroreflectivity*

- 5-600: *Florida Test Method for Determining the Retroreflectivity of Pavement Marking Materials Using Mobile Retroreflectivity Unit*

QUALIFIED PRODUCT LIST (QPL) REQUIREMENTS

- 630-020-001-f: *Transportation Product Evaluation*

FDOT STANDARD SPECIFICATIONS FOR BRIDGE AND ROAD CONSTRUCTION

- Section 706: *Raised Retroreflective Pavement Markers and Bituminous Adhesive*

- Section 709: *Traffic Stripes and Markings: Two Reactive Components*

- Section 710: *Painted Pavement Markings*

- Section 711: *Thermoplastic Traffic Stripes and Markings*
- Section 713: *Permanent Tape Stripes and Markings*
- Section 970: *Materials for Raised Retroreflective Pavement Markers and Bituminous Adhesive*
- Section 971: *Traffic Marking Materials*

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