



Operations Manual

L-743 Ultra-Precision Triple Scan[®] Laser

L-733 Precision Triple Scan[®] Laser

L-742 Dual Scan[®] Ultra-Precision Roll Alignment Laser

L-732 Dual Scan[®] Precision Roll Alignment Laser

February 2019



**HAMAR
LASER[®]**
ALIGN WITH THE BEST

HAMAR LASER INSTRUMENTS, INC.
www.hamarlaser.com

Five Ye Olde Road, Danbury, CT 06810
Phone: (800) 826-6185 Fax: (203) 730-4611

Important Notices

Please Read First

CAUTION!

Surge Protection Strongly Recommended

To ensure the long life of your laser, it is important to plug the A/C adapter into a surge-protected power source. Despite internal surge protection, a large power surge may cause the laser diode to burn out, requiring the laser to be returned to the factory for extensive repair. Failure to plug the A/C adapter into a surge-protected power source may void the warranty.

Laser Warm Up

Your new laser has been calibrated while it is fully warmed up. In order to ensure proper calibration, we recommend that you let your laser warm up for at least 30 minutes for single-plane lasers (L-730 or L-740) and up to 45 minutes for multi-plane lasers (L-732, L-742, L-733 and L-743).

This does not mean the laser spindles need to be rotating; only that the laser beam should be turned on for the recommended time.

You can use your laser prior to the warm up time to buck it in (make it parallel) to your references. However, doing this may result in some laser drift. Accordingly, if you use the laser prior to the warm-up period, it is recommended that you go back and check your references before you start taking the alignment measurements. For best results, do not start taking measurements until the recommended warm time has passed.

It is always a good metrology practice to periodically check your reference points to ensure the laser or the base (instrument stand, table or other supporting base) it sits upon has not drifted. Please note that most drift problems are caused by what the laser sits upon, not due to the laser drifting itself (after the warm up period).

Please call 1-800-826-6185 or +1-203-730-4600 if you have any questions or concerns.

WARRANTY

Hamar Laser Instruments, Inc., warrants each instrument and other articles of equipment manufactured by it to be free from defects in materials and workmanship under normal use and service, its obligation under this warranty being limited to making good at its factory any instrument and other article of equipment which shall, within one year after shipment of each instrument and other article of equipment to the original purchaser, be returned intact to Hamar with transportation prepaid, and which Hamar's examination shall disclose to Hamar's satisfaction to have been thus defective; other than this express warranty, Hamar neither assumes nor authorizes any other persons to assume for it any other liability or obligation in connection with the sale of its products.

This warranty is not applicable to instruments or other articles of equipment manufactured by other companies and limited by a warranty extending for less than one year. In such an event, the more limited warranty applies to said instrument or article of equipment.

This warranty shall not apply to any instrument or other article of equipment which shall have been repaired or altered outside the Hamar factory, nor which has been subject to misuse, negligence, or use not in accord with instructions furnished by the manufacturer.

The software described in this manual is furnished under a license agreement and may be used or copied only in accordance with the terms of the agreement. It is against the law to copy the software on any medium for any purpose other than the purchaser's personal use.

The information in this manual is subject to change without notice. No part of this manual may be reproduced by any means, electronic or mechanical, without written permission from Hamar Laser Instruments, Inc.

**© Copyright Hamar Laser Instruments, Incorporated, 2019
5 Ye Olde Road, Danbury, Connecticut 06810**

Table of Contents

The L-743 Ultra-Precision Triple Scan® Laser	1
The L-733 Precision Triple Scan® Laser	3
The L-742 Dual Scan Ultra-Precision Roll Alignment Laser	4
The L-732 Dual Scan Precision Roll Alignment Laser	5
Laser Controls	6
Differences in the Lasers	6
Providing Power to the Laser	7
Warming Up the Laser	7
Using the Control Panel	8
The Precision Level Vials	9
Reading the Precision Level Vials	9
Reading the L-740SP Split-Prism Level Vials	9
Calibrating the Level Vials	9
Zeroing the Targets	10
Calculating the Calibration of the Level Vials – Roll Axis	10
Setting the First Level Vial – Roll Axis	12
Calculating the Calibration of the Levels Vials – Pitch Axis	12
Setting the First Level Vial – Pitch Axis	13
Checking the Levels for Accuracy	13
Measurement Overview	14
Selecting Reference Points on Machine Tools	14
Selecting Reference Points on Process Mills	14
Measurement Summary	15
Measuring Straightness	15
Measuring Flatness	16
Measuring Squareness	16
Measuring Levelness	17
Measuring Parallelism	17
Level to Earth Measurements	17
Setting Up and Leveling the Laser	17
Laser Buck-in	18
Three Point Buck-In (Flatness)	18
Three Point Buck-In Procedure Using One Target	18
Setting up the Equipment	18
Performing the Three Point Buck-In	19
Three Point Buck-In Procedure Using Multiple Targets	20
Two Point Buck-In (Straightness)	20
Normal versus Remote Buck-In	21
Normal Buck-In	21
Remote Buck-In	22
Appendix A – Troubleshooting Guide	24
Appendix B – Equipment Drawings	27
Appendix C – Interpreting the A-1519/1520 Type II Calibration Reports	31
Appendix D – Care and Cleaning of Target Optics	33

The L-743 Ultra-Precision Triple Scan® Laser

Warning!
*Always operate the L-730 and L-740 series lasers described below in an upright position.
Do NOT invert!*



The L-743 Ultra-Precision Triple Scan® Laser is Hamar Laser's most versatile and powerful machine tool alignment laser. It has been designed specifically for 3-5-axis machining centers to measure and correct machine geometry. In most cases, all it takes is one setup to measure flatness, straightness, parallelism and squareness of the main axes of most typical machining centers.

Since the system provides live measurements, any errors that are found can be fixed with the same setup. The laser mounts on a machine or stable base so that the laser plane can project the measurement reference out to 100 ft. (30.5 m) in radius for each laser plane.

Applications: (for alignments with tolerances of 0.00002 in/ft or 0.0017 mm/m or greater)

- Machining centers (HBMs, VBMs, HMCs, VMCs, VTLs, gantries and surface grinders)
- Aircraft assembly (seat track alignment, setting water, butt and station planes, wing-to-body and body-to-body join alignment, etc.)
- Automotive transfer-line wing bases
- Injection molding machines and presses

Roll parallelism in:

- High-precision, laser and water-jet cutting machines
- Circuit board drilling machines
- Paper mills
- Printing presses
- Film lines
- Blown-film lines

Measuring and aligning:

- The flatness of almost any surface (squares, frames, ways, flanges, circles, etc.)
- The squareness of up to 3 surfaces
- Measuring surfaces up to 200 ft. (61 m) long with one setup
- The parallelism of horizontal and vertical surfaces even if those surfaces are 100 ft. (30.5 m) apart
- Checking way twist and parallelism between horizontal surfaces
- The straightness of horizontal and vertical surfaces
- The straightness and flatness of horizontally and vertically traversing axes
- Checking plumb of a vertical surface up to 100 ft. (30.5 m)
- Checking way twist and parallelism between vertical surfaces

Features

- 3 continuously rotating laser planes with operational range of 100 ft. (30.5 m) in radius.
- Instant on with virtually no warm-up
- Planes are mutually square to 1 arc sec (.00006 in/ft or 0.005mm/m).
- Levels accurate to 1 arc second (.00006 in/ft or 0.005mm/m).
- Targets provide live data display
- Uses A-1520 Single-Axis Wireless Target with 1 Micron (.00004 in.) resolution for higher accuracy applications.
- Laser and targets fit into a small, portable shipping case
- Diode laser 2 times more stable than HeNe based laser systems
- Battery or AC powered
- Laser planes flat to $\frac{1}{2}$ arc seconds (.00003 in/ft or 0.0025mm/m) in 180° sweep and $\frac{1}{4}$ arc second (.00001 in/ft or 0.0008mm/m) in 90° sweep).
- Includes Pitch/Roll/Yaw base with coarse and fine adjustments and lighted levels.
- Standard target: A-1519-2.4ZB Single-Axis Wireless Target with 1 in. measuring range and .0001 in. resolution.
- System uses Windows-based software for quickly recording and analyzing machine geometry data
- Typical setup time 20 minutes or less
- Completely self-contained

The L-733 Precision Triple Scan[®] Laser



The L-733 Triple Scan Laser was specifically designed for machining centers to measure and correct machine geometry. It has all of the innovative and highly useful features of the L-743 Ultra-Precision Triple Scan Laser, with lower accuracy and a medium adjustment base. It is very useful for checking the alignment of large fabrications or aligning large airplane sections in aircraft manufacturing.

In most cases, all it takes is one setup to measure flatness, straightness, parallelism and squareness. Since the system provides live measurements, any errors that are found can be fixed with the same setup. The laser mounts on a machine or stable base so that the laser plane can project the measurement reference out to 100 ft. (33 m) in radius for each laser plane.

Applications: (for alignments with tolerances of .0005 in/ft or (0.038 mm/m) or greater)

- Machining centers (HBM, VBM, VTL, VMC, HMC, gantries, surface grinders)
- Checking the alignment of large bearing surfaces and fabrications
- Aircraft assembly (seat track alignment, setting water, butt and station planes, wing-to-body and body-to-body join alignment, etc.)
- Water jet and laser cutting machines
- Leveling machine beds and ways
- Roll alignment (rubber, steel, textile and lower accuracy film lines)
- Saw mills
- Vertical press alignment

Measuring and aligning:

- The flatness of almost any horizontal or vertical surface (squares, frames, ways, flanges, circles, etc.) or axes
- The squareness of any 2 vertical surfaces or axes
- Way twist and parallelism between vertical or horizontal surfaces
- Way twist and parallelism between vertical or horizontal surfaces
- Checking plumb of a vertical surface up to 100 ft. (33 m)
- The straightness of vertical and horizontal axes
- Measuring surfaces up to 200 ft. (66 m) long with one setup
- The parallelism of vertical or horizontal surfaces, even if those surfaces are 100 ft. (33 m) apart
- The squareness of any vertical machine axis or surface to horizontal axis or surface

Features:

- Continuously rotating laser planes with operational range of 100 ft. (33 m) in radius.
- Completely self-contained
- Standard target: A-1519-2.4ZB Single-Axis Wireless Target providing live data display
- System uses Windows-based software for quickly recording and analyzing machine geometry data
- Typical setup time 20 minutes or less
- Diode laser 2 times more stable than HeNe-based laser systems
- Laser planes flat to 2 arc seconds in 180° sweep and 1 arc-second in 90° sweep. Planes are mutually square to 2 arc seconds.
- Includes Pitch/Roll/Yaw base with medium-resolution adjustments and lighted levels. Levels accurate to 2 arc seconds.
- Instant ON, with virtually no warm up
- Battery or AC powered

The L-742 Dual Scan Ultra-Precision Roll Alignment Laser



With two continuously sweeping, ultra-flat, orthogonal laser planes, the L-742 is ideally suited to roll alignment applications. The laser can be configured at the factory to have either two vertical planes, or one horizontal and one vertical plane, allowing a user to not only measure, but also fix alignment problems in a fraction of the time needed with conventional methods.

Using the L-742 you can quickly and easily check and correct horizontal roll parallelism of even the tallest process mills, pick up and check offset centerline benchmarks, and perform similar alignments with increased accuracy and shorter setup times.

Applications: (for alignments with tolerances of .00002 in/ft or 0.0017 mm/m or higher)

- Roll parallelism in paper mills, printing presses and film lines
- Roll forming machines
- High-precision, laser and water-jet cutting machines
- Measuring surfaces up to 200 ft. (61 m) long with one setup
- Circuit board drilling machines
- Leveling almost any surface (squares, frames, ways, flanges, circles, etc.)
- Checking plumb of a vertical surface up to 100 ft. (30.5 m)
- Checking way twist and parallelism between surfaces

Measuring and aligning:

- The flatness and straightness of almost any surface (squares, frames, ways, flanges, circles, etc.)
- The parallelism of vertical or horizontal surfaces, even if those surfaces are 100 ft. (30.5 m) apart
- The flatness and straightness of horizontally and vertically traversing axes
- The squareness of any two surfaces
- The flatness and straightness of vertical surfaces

The L-732 Dual Scan Precision Roll Alignment Laser



Primarily designed for roll alignment and other similar alignment applications that do not require the exacting tolerances of the L-742 Ultra-Precision Laser, the L-732 Precision Dual Scan Laser also offers two automatically rotating laser planes that can be configured at the factory to have either two vertical planes, or one horizontal and one vertical laser plane. The L-732 laser planes are flat and square to 2 arc seconds (.00012 in/ft or 0.01 mm/m). It comes with a pitch, roll and yaw adjustment base for setting the laser planes parallel to reference points, 2-arc-second level vials and a powerful magnet for maximum stability.

Applications: (for alignments with tolerances of .00015 in/ft or (0.01 mm/m) or greater

- Normal or blown-film lines (roll alignment)
- Rubber (roll alignment)
- Laser cutting machines
- Water-jet cutting machines
- Steel (roll alignment)
- Saw Mills
- Textiles (roll alignment)
- Leveling almost any surface (squares, frames, ways, flanges, circles, etc.)
- Checking plumb of a vertical surface up to 100 ft. (30.5 m)
- Checking way twist and parallelism between vertical surfaces

Measuring and aligning:

- The flatness of almost any vertical surface (squares, frames, ways, flanges, circles, etc.)
- The parallelism of vertical or horizontal surfaces, even if those surfaces are 100 ft. (30.5 m) apart
- Measuring surfaces up to 200 ft. (61 m) long with one setup
- The straightness of horizontally and vertically traversing axes
- The squareness of any two vertical surfaces
- The flatness and straightness of vertical surfaces

Laser Controls

Differences in the Lasers

The differences in the four laser models discussed in this manual are as follows:

- **Accuracy:** the L-743 and L-742 are four times more accurate for flatness and two times more accurate for squareness than the L-733 and L-732. The L-733 and L-732 have a pitch/roll/yaw base with medium adjustments and the L-743 and L-742 have a pitch/roll/yaw base with both coarse and fine adjustments (see Figure 1).
- **Number of laser planes:** the L-743 and the L-733 have three laser planes and the L-742 and L-732 have two laser planes that can be factory-configured for two vertical planes (wall/wall) or one vertical and one horizontal plane (wall/ceiling).

When drawings are used to describe a procedure, the laser model will be identified in the caption. However, the procedures themselves are essentially the same for all four lasers. Appendix A, beginning on Page 24, provides detailed drawings and specifications for each laser model.

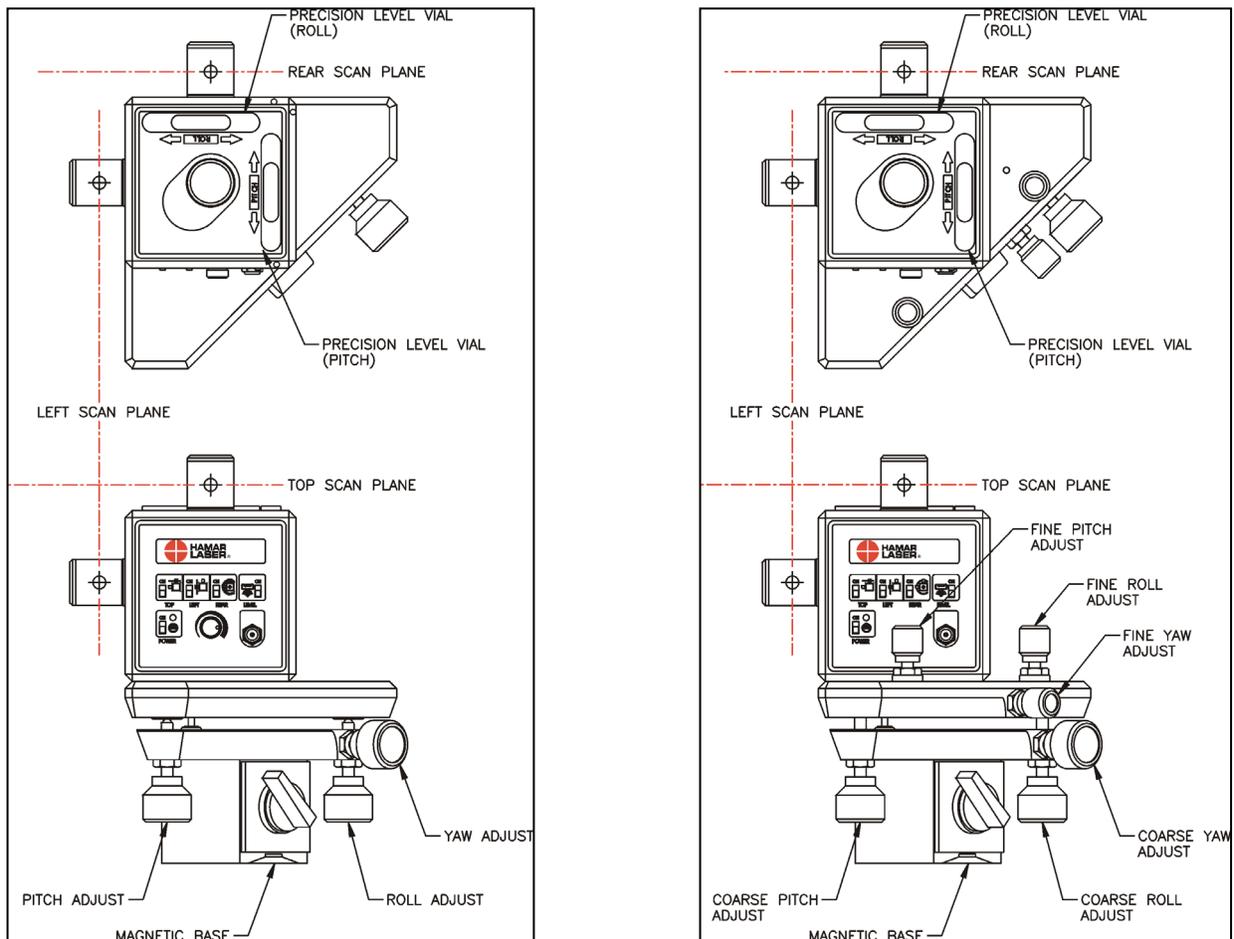


Figure 1 – L-733 Laser (left) and L-743 Laser (right) top and side views

Providing Power to the Laser

Power to the laser is supplied by either an external battery pack using four 9V cells, (Hamar Laser recommends using alkaline or NiCad cells for best performance) or by a 115V AC adapter (see Figure 2 for the location of the battery pack/AC adapter connection on the laser control panel). The laser uses more power with each additional scanner that is activated.

CAUTION!

Surge Protection Strongly Recommended

To ensure the long life of your laser, it is important to plug the A/C adapter into a surge-protected power source. Despite internal surge protection, a large power surge may cause the laser diode to burn out, requiring the laser to be returned to the factory for extensive repair. Failure to plug the A/C adapter into a surge-protected power source may void the warranty.

Warming Up the Laser

Your new laser has been calibrated while it is fully warmed up. In order to ensure proper calibration, we recommend that you let your laser warm up for at least 30 minutes for single-plane lasers (L-730 or L-740) and up to 45 minutes for multi-plane lasers (L-732, L-742, L-733 and L-743).

This does not mean the laser spindles need to be rotating; only that the laser beam should be turned on for the recommended time.

You can use your laser prior to the warm up time to buck it in (make it parallel) to your references. However, doing this may result in some laser drift. Accordingly, if you use the laser prior to the warm-up period, it is recommended that you go back and check your references before you start taking the alignment measurements. For best results, do not start taking measurements until the recommended warm time has passed.

It is always a good metrology practice to periodically check your reference points to ensure the laser or the base (instrument stand, table or other supporting base) it sits upon has not drifted. Please note that most drift problems are caused by what the laser sits upon, not due to the laser drifting itself (after the warm up period).

Using the Control Panel

Figure 2 shows the control panel for the L-743 and L-733 lasers, including the locations of:

- The battery pack/AC adapter connection
 - The power switches and POWER ON indicator for the laser
 - The power switches for the individual scanners
 - The light for the precision level vials
- Note:** As of January 1, 2014, the level light switch has been modified. The level light now stays on permanently to increase stability and allow the laser to warm up faster.
- The rotation speed control. This control slows the scanner spin until you can see the laser beam pass over the target (the farther away the target is located, the slower the turret must spin).

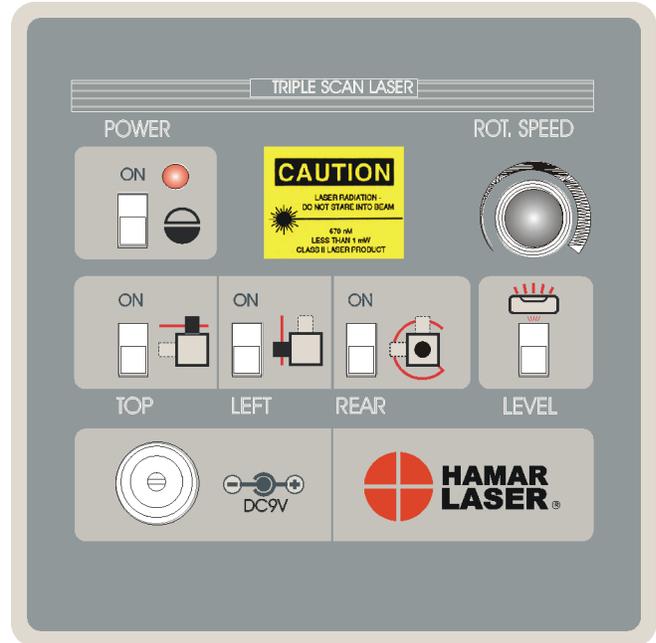


Figure 2 -- Laser Control Panel—L-743 and L-733 Lasers

Figure 3 shows controls panel for the L-742 and L-732 lasers, both the “Wall-Wall” configuration with two vertical laser planes, and the “Wall-Ceiling” configuration, with one vertical laser plane and one horizontal laser plane.

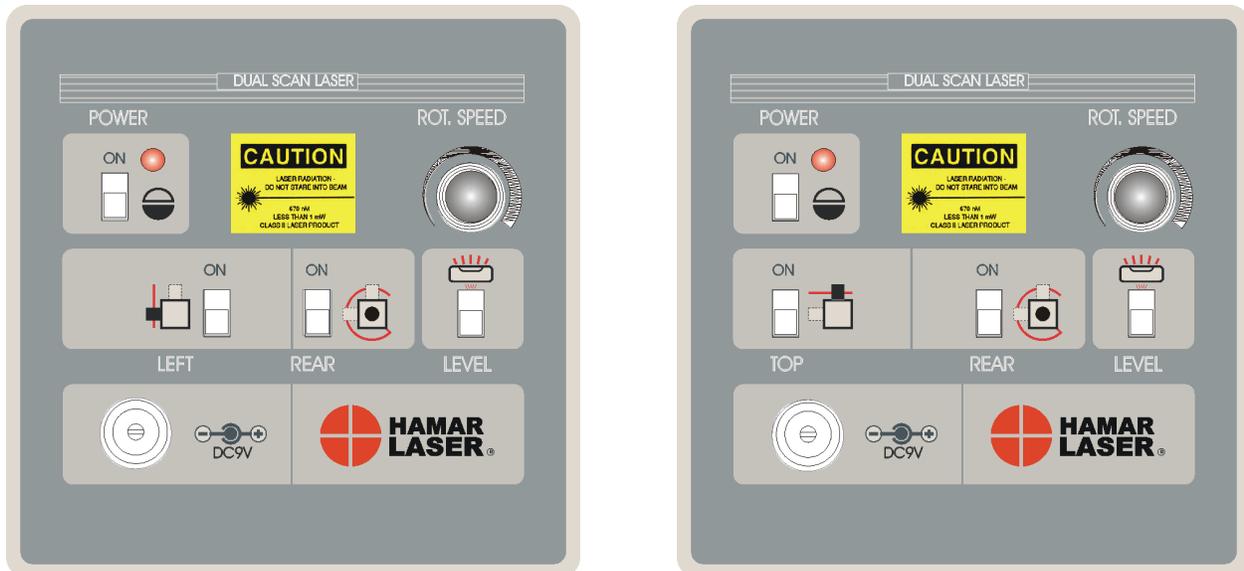


Figure 3 – Laser Control Panels for the L-742 and L-732 Lasers. On the left is the “Wall-Wall” configuration, or two vertical laser planes. On the right is the “Ceiling-Wall” configuration, or one vertical plane and one horizontal plane.

The Precision Level Vials

Please Note!

*Our level vials are designed to be calibrated **by the customer**. We cannot guarantee that the level vials are calibrated when you receive the equipment because of movement during shipping. Please follow the procedure below specific to the level vials on your laser.*

Reading the Precision Level Vials

Secure the laser base to a metal surface by turning the locking magnetic base ON. Once the laser is in position, power it on and light the level vials (if necessary) using the LEVEL switch located on the control panel. Use the adjustment knobs to bring the bubbles to the center of both vials (see Figure 4).

When both the PITCH and ROLL vials are reading level, a level beam can be scanned at 360 degrees with a .0003 in. deviation per 10 ft.



Figure 4 – Precision Level Vial entered (top) and off center (bottom)

Reading the L-740SP Split-Prism Level Vials

Once the laser unit is in position on the base, connect power to the base power supply input jack and press the red button to light the precision level vials. Use the *coarse* alignment micrometers to bring the bubbles to the center of the vials.

When the bubbles are close to the center, use the *fine* adjustment micrometers to align the bubble halves to each other in the viewing prism window (see Figure 5). When both the long axis and short axis vials are reading level, a level beam can be scanned at 360 degrees with a .0003 in. deviation per 10 ft.

Calibrating the Level Vials

Note 1: *This procedure calibrates only one level vial at a time and must be repeated for the other axis.*

Note 2: *It is very important to warm up the laser for at least 30 minutes before starting this procedure. It is also very important to level both the Pitch and Roll axis level vials during this procedure. Failure to do this makes it nearly impossible to calibrate the levels.*

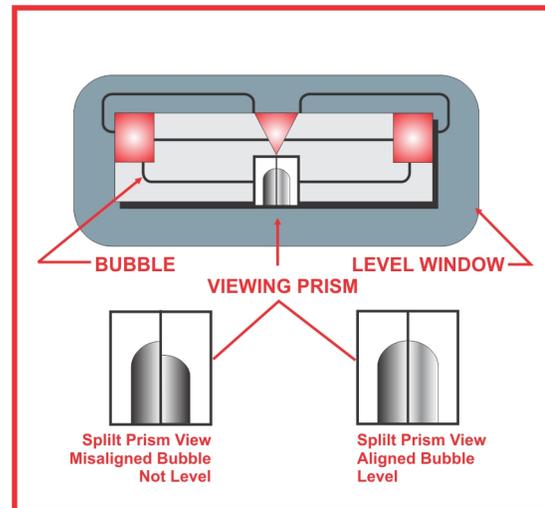


Figure 5 –L-740SP Split-Prism Level Vial Assembly for L-740 Series Lasers

The calibration procedure involves a series of steps to adjust the laser beam to be level to earth. Because the leveling process is subject to so many variables, repeat the procedure to check for accuracy once the initial readings are taken and adjustments are made. A typical sequence would be as follows:

- *Determine* the set point and set the first axis.
- *Use* the set point value to set the second axis.
- Check both the first and second axes. Reset the levels if necessary.
- If the levels are reset, make a final check to determine if the laser level error is acceptable.

When calibrating the precision level vials, work on a surface that is level to earth within .001 to .002 in/ft. A surface that is 10 to 20 ft. in length is ideal. When calibrating to shorter surfaces, do so with the readout set to the .0001 in. mode. If you are using the A-1519 or A-1520 Wireless Targets with the R-1356 PDA or with Hamar Laser's alignment programs, set the readout display through the software.

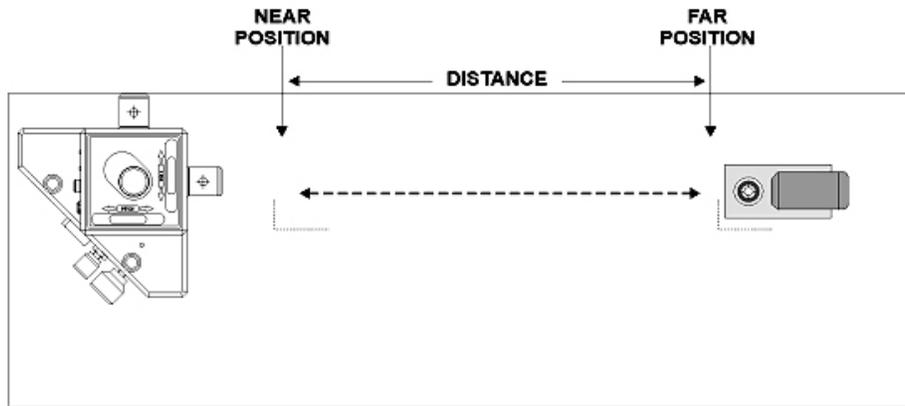


Figure 6 -- Laser and Target Setup for Calibrating the Precision Level Vials

Zeroing the Targets

The following sections refer frequently to “zeroing” the target. When a target is zeroed, the readout is reset to zero at the point where the laser beam currently hits the target cell.

When using the A-1519/A-1520 Universal Targets, this is accomplished through the Read15 software (or through Hamar Laser's other alignment programs). This reading is stored in memory and then subtracted from all future readings. Once the target is zeroed, subsequent readings show only the *difference* from the original reading.

Calculating the Calibration of the Level Vials – Roll Axis

Note: *It is very important to warm up the laser for at least 30 minutes before starting this procedure. It is also very important to level both the Pitch and Roll axis level vials during this procedure. Failure to do this makes it nearly impossible to calibrate the levels.*

1. Level the laser.

Using the adjustment knobs, level the laser so *both* the pitch and roll levels are exactly level (see top of Figure 4).

2. Zero the target in the Near Position.

Beginning with the Roll Axis, place a target on a point near to the laser. Mark this point so you can always reposition the target at the same point. Zero the target according to the readout you are using.

3. Determine Far Reading 1.

Move the target to the Far Point, mark this point and record the target reading. This is *Far Reading 1*. Measure the distance (D1) between the Near Point and the Far Points and write it down.

Note: *It is recommended to repeat the measurements two or three times to check repeatability.*

4. Determine Far Reading 2.

Rotate the entire laser unit 180 degrees. Re-level the laser using the adjustment knobs so *both* the pitch and roll levels are exactly level. Return the target to the Near Position, ensuring that it is placed

in the exact position as before. Re-zero the target on this point. Move the target back to the Far Position, again ensuring that it is positioned exactly as before. Record the target reading. This is *Far Reading 2*.

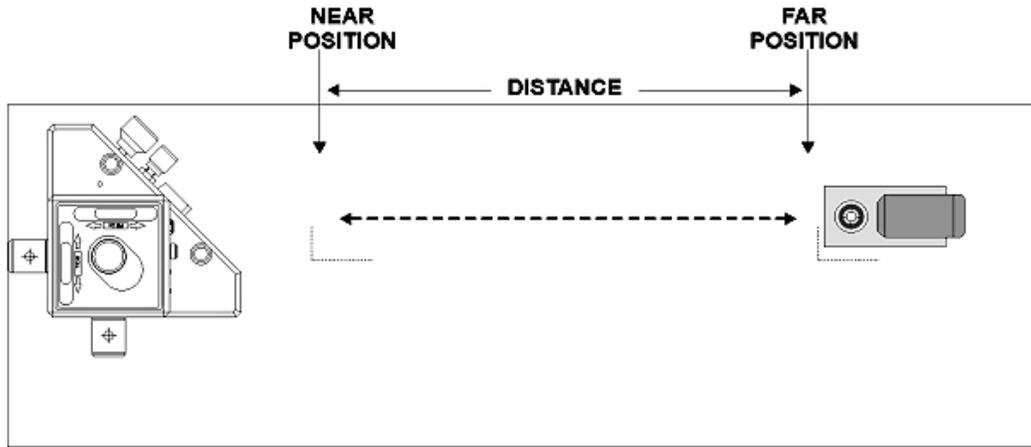


Figure 7 -- Setup after rotating the laser 180 degrees

5. Calculate the Set Point – Roll Axis

Add Reading 1 and Reading 2 and divide by 2 (Set Point). Divide the Set Point by the D1 (distance between the points). The result is the calibration of the level vial in units of in/ft or mm/m. To be within specifications, the calibration result should be as follows:

- Split Prism Vial Assembly: \leq .00006 in/ft (0.005 mm/m)
- Standard Levels: \leq .00012 in/ft (0.01 mm/m)

Example:

15 ft. (D1)
 .000 (Near Reading)

 .020 (Far Reading 1)
 + -.010 (Far Reading 2)

 +.010 (Sum of the two readings)

 +.010 / 2 = +.005 (Set Point)

Calibration = Set Point / D1
 .005 / 15 = .0003 in/ft (out of spec)

If this value is out of the specification, then you will need to use the Set Point to bring it back into specification. See the first step in the next section.

Setting the First Level Vial – Roll Axis

6. Tilt the laser to the Set Point

Move the target back to the Near Point to verify it still reads zero. If not, re-zero it. Then move the target back to the Far Point and tilt the laser by adjusting the Roll Axis adjustment knob on the laser base until the readout displays the calculated Set Point.

7. Adjust the level.

Locate the two recessed adjustment screws for the Roll Axis level you are adjusting (see Figure 8). Using the wrench provided, adjust the level assembly until the bubble is centered in the window for the Standard Level Vials or the two halves of the bubbles line up for the Split Prism Level Vial (see Figure 4 and Figure 5). For example, to move the bubble to the left, loosen the left screw and tighten the right screw. When the bubble is centered, tighten the left screw until the bubble is stationary. Check your work by repeating these steps and ensuring that the level is calibrated to within the specified tolerances.

Note: Tighten the set screws just firmly enough to hold the window assembly in place. Over-tightening these screws may cause damage.

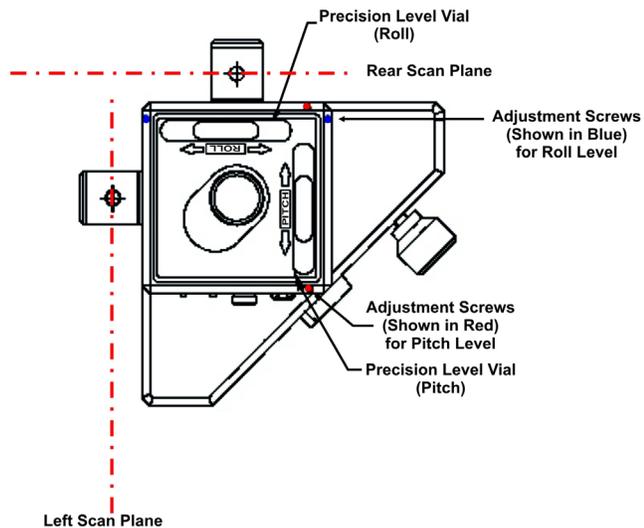


Figure 8 – L-733 (top view) showing location of Precision Level Vials and corresponding adjustment screws

Calculating the Calibration of the Levels Vials – Pitch Axis

1. Level the laser.

Rotate the entire laser unit 90° to calibrate the Pitch Axis level vial. Using the adjustment knobs, level the laser so that *both* the pitch and roll levels are exactly level.

2. Zero the target in the Near Position.

Set the target on the same Near Position as before and re-zero it.

3. Determine Far Reading 1.

Move the target to the same Far Position as before and repeat Step 3 (Roll Axis) above.

4. Determine Far Reading 2.

Rotate the entire laser unit 180°. Re-level the laser using the adjustment knobs so *both* the pitch and roll levels are exactly level. Return the target to the Near Position, ensuring that it is placed in the exact position as before. Re-zero the target on this point. Move the target back to the Far Position, again ensuring that it is positioned exactly as before. Record the target reading. This is **Far Reading 2**.

5. Calculate Level Calibration and the Set Point – Pitch Axis

Add Reading 1 and Reading 2 and divide by 2 (Set Point). Divide this Set Point by the D1 (distance between points). The result is the calibration of the level vial in units of in/ft or mm/m. To be in specification, the calibration result should be as follows:

Split Prism Vial Assembly: $\leq .00006$ in/ft (0.005 mm/m)
 Standard Levels: $\leq .00012$ in /ft (0.01 mm/m)

Example:

15 ft. (D1)
 .000 (Near Reading)
 .035 (Far Reading 1)
 + .010 (Far Reading 2)

 .045 (Sum of the two readings)
 +.045 / 2 = +.0225 (Set Point)

Calibration = Set Point / D1
 .0225 / 15 = .0015 inches/ft. (out of spec)

If this value is out of the specification, then you will need to use the Set Point to bring it back into specification. See Step 6 below.

Setting the First Level Vial – Pitch Axis

6. Tilt the laser to the Set Point

Move the target back to the Near Point to verify it still reads zero. If not, re-zero it. Then move the target back to the Far Point and tilt the laser by adjusting the Pitch Axis adjustment knob on the laser base until the readout displays the calculated Set Point.

7. Adjust the level.

Locate the two recessed adjustment screws for the Pitch Axis level you are adjusting). Using the wrench provided, adjust the level assembly until the bubble is centered in the window for the Standard Level vials or the two halves of the bubbles line up for the Split Prism Level vial (see Figure 4 and Figure 5). For example, to move the bubble to the left, loosen the left screw and tighten the right screw. When the bubble is centered, tighten the left screw until the bubble is stationary. Check your work by repeating these steps and ensuring that the level is calibrated to within the specified tolerances.

Note: Tighten the set screws just firmly enough to hold the window assembly in place. Over-tightening these screws may cause damage.

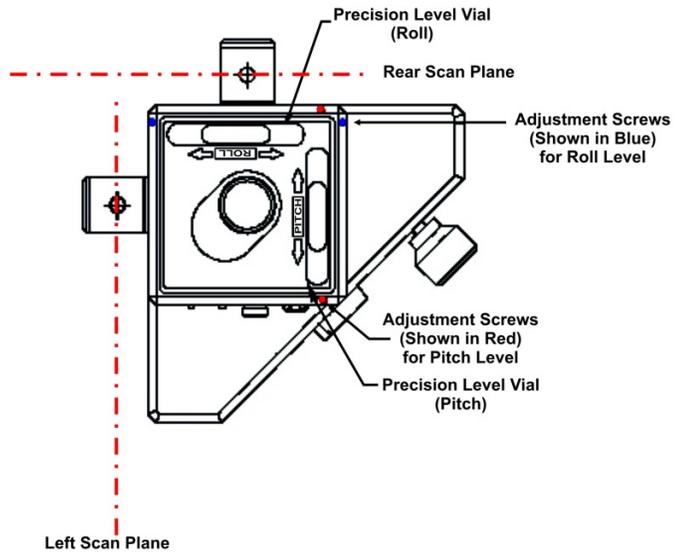


Figure 9 – L-733 (top view) showing location of Precision Level Vials and corresponding adjustment screws

Checking the Levels for Accuracy

To check for accuracy, repeat the steps for setting the precision level vials. The Set Point should be the same as the previous Set Point. If not, calculate a new set point and adjust as necessary.

Measurement Overview

In general, a laser is used for alignment by making it parallel to *reference points* and using a target to measure deviations from those points. Reference points are points chosen on a surface or in a bore that represent the starting point for which all other points on the surface or in a bore will be compared. For bore, spindle and rotating shaft applications, two reference points are needed to establish a *datum*, or the basis used for calculating and measuring. For surfaces, three reference points are needed to establish a datum.

For continuously rotating laser applications, like machining centers and presses, three to five reference points are needed, although Level to Earth Measurements are frequently used instead of reference points. Laser *buck-in* refers to the adjustment of a laser plane or beam to be parallel to the reference points (a table top, a surface plate, or a way surface).

Once the laser is "bucked in," any point within range of the laser device, typically up to 100 ft. (30.5 m), can be measured for deviation in one axis for rotating laser applications. One of the principal advantages of geometry lasers is that they provide live alignment data, which means a machine or part may be aligned without moving or changing the laser's setup. In effect, the targets act as a live digital indicator of the alignment. When the target reads zero, the point is aligned and the next point is measured.

Selecting Reference Points on Machine Tools

When using a laser system or any other alignment method, it is important to select reference points carefully. Poor reference points, like those on the heavily worn portion of a machine bed where all the work is performed, may mean extra time to bring the machine back into tolerance. In other words, it could be the reference points that need alignment rather than the rest of the axis.

In metrology, it is recommended that some sort of data analysis be performed on a machine's axis before proceeding to the alignment stage. This step may save countless hours when aligning a machine tool that has only a couple of bad points. Typically, a least-squares, best-fit algorithm is applied to a set of data for an individual axis. This algorithm calculates a line or a plane that best fits the data and will quickly show any bad data points. The data can also be adjusted so the alignment for each point would bring it parallel to the best-fit line or plane.

Selecting Reference Points on Process Mills

Conventional methods of roll alignment usually use floor benchmarks (monuments) at the side of the machine as references. The L-742 and L-732 offer the versatility of using the benchmarks or of picking up a reference roll, such as a cooch roll on paper mills. However, we strongly believe that using a reference roll provides a more accurate reference and results in better alignments.

Benchmarks are usually set in a thin concrete floor, are rarely covered, and are routinely run over and nicked. More importantly, they move with their slab of concrete and rarely hold their position relative to the mill itself. Most floors in a typical plant have multiple slabs and are usually cracked throughout, creating instability of the monuments. Unless checked every time they are used, the use of the benchmark probably will result in significant alignment errors.

Measurement Summary

The following section is a brief summary of how the laser is used to measure straightness, flatness, squareness, levelness and parallelism. Note that if a machine is going to be aligned, rather than just measured, it is important to put the laser on an instrument stand. If the laser is on the machine bed or table, adjustments will likely move the laser and affect the setup.

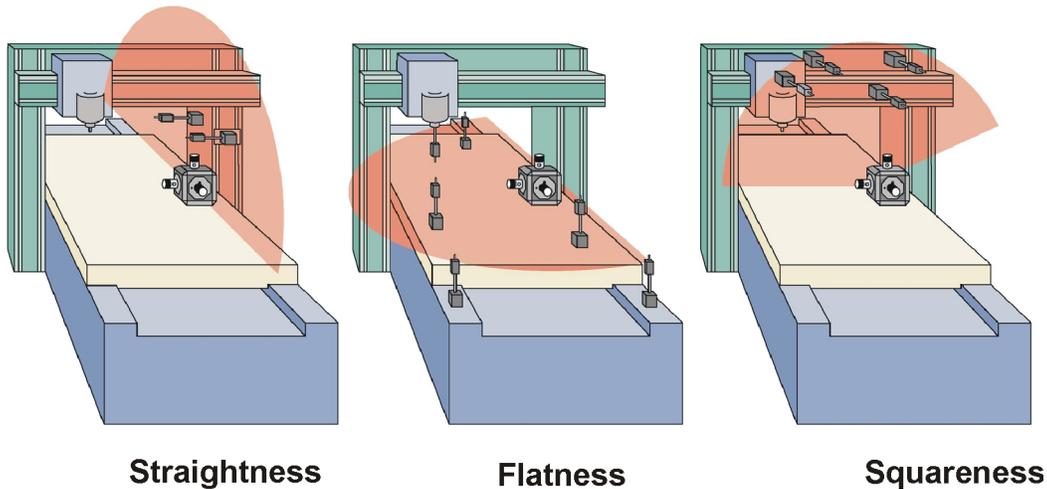


Figure 10 – Measuring Straightness, Flatness and Squareness

Measuring Straightness

To measure (horizontal) straightness of a surface or machine axis, two reference points and one vertical laser plane are needed.

- 1. Mount a target horizontally at the *closest* reference point to the laser and adjust the target so that it detects the laser.**
- 2. Zero the target and move it to the *farthest* reference point from the laser. Use the YAW adjustment to produce the same reading for both reference points.**
The laser is now parallel or “bucked in” to the reference points.
- 3. Place the target at intervals along the surface or machine axis.**
Any deviations from zero are a measure of straightness relative to the reference points. If the target is mounted so that its top is to the left of the laser plane, then a “+” reading means the measured point is to the “left” of the reference points and a “-” reading means the point is to the right of the reference points.

Measuring Flatness

To measure flatness, a horizontal, continuously rotating laser plane is “bucked in” or adjusted so that it is parallel to three reference points on a table, set of ways, or a surface.

1. **Place all the targets on one reference point and adjust them up or down so they detect the laser plane.**
2. **Zero the targets.**
3. **Reposition the targets so that one target sits on each reference point.**
4. **Using the PITCH and ROLL adjustments, adjust the laser scan plane until all three targets produce the same value or zero, thus making the laser parallel to the reference points.**

This may also be accomplished by using one target, zeroed on the closest reference point to the laser, and moving it back and forth from the reference points until it produces a reading of zero at all three points.

5. **Move the target to user-specified points on the surface.**

The resulting reading is a measure of the deviation from the reference point, helping to produce a flatness profile. The measurement will show either a plus (+) or a minus (-) sign. A plus reading indicates that the target is *higher* than the reference points and a minus reading means the target is *lower* than the reference points.

Measuring Squareness

After bucking in the laser to the five reference points described in Measuring Straightness and Measuring Flatness, (to determine the straightness and flatness of the machine's axes) measuring squareness is a simple process. To *truly* measure squareness, one must compare the least-squares, best-fit line of the one axis to the other axis. If this is not done, bad reference points or severely worn ways might produce what looks like a squareness error, but in fact is not. To facilitate this type of analysis, our software programs may be used to automatically calculate the best-fit line.

To measure Y-to-Z squareness:

1. **Lower the column/spindle to its lowest Z position and position a target horizontally to pick up the vertical laser plane that is perpendicular to the X-axis (parallel to the Y-axis).**
2. **Zero the target and traverse (raise) the column along its axis.**

The data produces a measurement of both the straightness of the Z-axis and the squareness of the Y-axis to the Z-axis.

To measure Z-to-X squareness:

1. **Position and zero the target to detect the vertical laser plane that is parallel to the X-axis.**
2. **Traverse the column upward.**

The resulting data is a measure of the Z flatness and Z-to-X squareness.

To measure X-to-Y squareness:

1. **Position and zero the target to detect the vertical laser plane that is parallel to the X-axis.**
2. **Traverse the table or column (whichever is moveable) along the Y-axis.**

The result is a measure of both Y straightness and X-to-Y squareness.

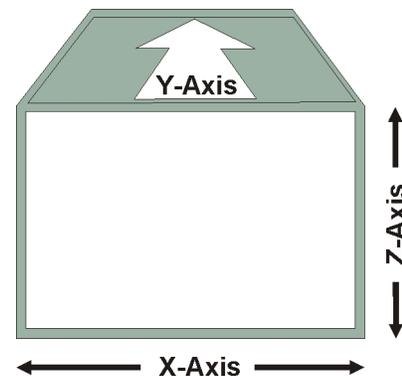


Figure 11 – The X, Y and Z Axes

Measuring Levelness

1. **Level the laser using the built-in level vials.**
2. **Place a target on one reference point, adjust it up or down so that it detects the laser plane, and zero the target.**
3. **Moved the target to any other point on the surface to see the deviation of that point from the reference point.**

Measuring Parallelism

1. **Buck in the laser plane to three reference points on the first surface (see *Measuring Flatness*).**
2. **Place a target on the second surface on one reference point and adjust the target so it detects the laser plane.**
3. **Zero the target.**
4. **Move the target to other points on the surface.**
Any deviation from the reference point is a measure of the parallelism of the first surface to the second.

Note: At least three points should be measured. The best way to determine parallelism is to measure both surfaces with the laser plane and enter the data into Hamar Laser's Plane5 software, which calculates the least-squares best-fit plane for both surfaces and then compares them. When using Plane5, the "buck-in" procedure is not necessary because the software removes the slope error from the laser not being parallel to the surface.

Level to Earth Measurements

The leveling of machine tools, surface plates and different types of bases can be performed using scanning lasers, as follows:

Setting Up and Leveling the Laser

1. **Place the laser on any stable steel surface such as a machine bed or an L-106 floor stand.**
2. **Twist the magnetic lever on the base of the unit to the "ON" position.**
This locks the instrument down securely to the surface.
3. **Plug in and power on the laser.**
4. **Turn the adjustment knobs and adjust the tilt of the laser to exactly center the level bubble in each of the level vials.**
5. **Place a target on the unit that needs to be leveled or adjusted.**
Adjust the target height so that the beam scans near the middle of the target cell. Zero the readout.
6. **Set the target on various places on the surface to be leveled and adjust the unit until the readout reads zero.**
Once the laser has been leveled and the target has been set to zero, these two units will not be adjusted any further. Any further adjustments will be made in the unit to be leveled.

Note: Some users prefer to take readings at the various leveling points to find the highest point, and then use the highest point to set the target to zero and bring all the other points up to this height.

Laser Buck-in

The following section covers laser buck-in procedures in detail, including the three point buck-in for flatness, the two point buck-in for straightness, and the differences between Normal and Remote buck-in.

Three Point Buck-In (Flatness)

The Three Point Buck-In procedure requires adjusting the laser plane to be parallel to the surface being measured; for example, a table top, a surface plate, or a way surface. Three points are required in order to relate one plane to another. *Any* three points on a surface may be used, however Hamar Laser recommends the setup illustrated in Figure 12.

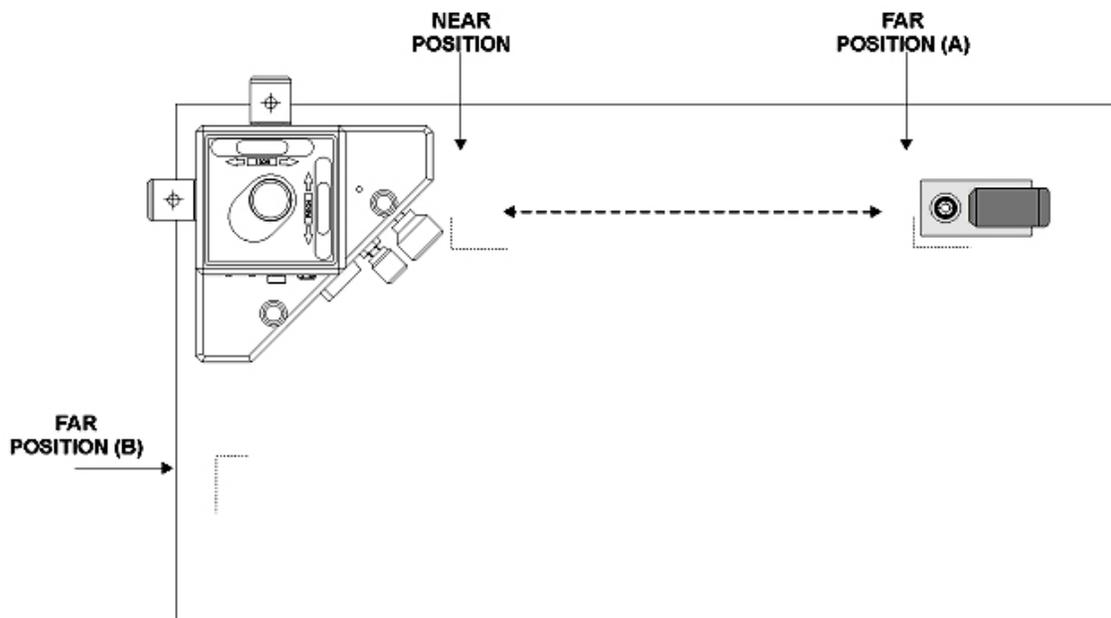


Figure 12 – Three Point Buck-in Using One Target (recommended setup)

When performing this procedure, it is best to place the laser source in a position that is as close to the near target position as possible. The third target position should be approximately 90° to these two points. This is not always possible, but this is the easiest configuration for this procedure.

Three Point Buck-In Procedure Using One Target

Setting up the Equipment

1. Position and secure the laser.

Position the laser as shown and turn the lever on the magnetic base to ON to lock it securely to the metal surface.

2. Coarse level the laser.

Power on the laser and use the speed control knob on the control panel slow the scanner spin until you can see the laser beam pass over the target (the farther away the target is located, the slower the scanner must spin). Turn the light switch for the bubble level vials ON. Using the adjustment knobs and observing the position of the precision level vials, coarse-level the laser so that the laser plane is approximately parallel to the surface.

3. Position and secure the target.

Place the target in the *Near Position* (see Figure 12). Move the target in its magnetic base until the laser beam roughly hits the mid-position of the target and turn the lever on the magnetic base to ON to lock it securely to the metal surface.

Note: As you move the target to the Near Position, Far Position A and Far Position B, mark where the base of the target sits on the surface so that it may be repositioned in the same place each time.

4. Set the readout.

If you are using the A-1519 or A-1520 Wireless Targets with the R-1309 system or with Hamar Laser's alignment programs, set the readout display through the software. You may also need to adjust the sampling rate to dampen the effects of atmospheric turbulence in the Read15 software (or in the Hamar Laser alignment program you are using).

Performing the Three Point Buck-In

1. Center the target in the Near Position.

With the target in the Near Position, zero the target.

2. Move the target to Far Position A and tilt the laser beam until the readout reads zero.

With the target in Far Position A, tilt the laser beam with the *laser* adjustment knobs until the readout reads zero. Be sure to use *only* the adjustment knobs that face the target (in the setup displayed in Figure 12, this would be the adjustment knob marked ROLL).

Note: When the target is in the Near Position, always use the appropriate zero function to center the target photocell. When the target is in the Far Position, always use the laser adjustment knobs to tilt the laser beam. This is easily remembered by the phrase, "Center Near, Tilt Far."

3. Repeat Steps 1 and 2 until the readout reads zero with no adjustments.

Continue to move the target between the Near Position and Far Position A, zeroing the target at the Near Position and tilting the laser beam using the adjustment knobs at the Far Position until the readout reads zero without adjustments.

4. Move the target to Far Position B and tilt the laser until the readout reads zero.

Be sure to use only the laser adjustment knobs that face the target when tilting the laser beam (in the setup displayed in Figure 12, this would be the PITCH adjustment).

5. Recheck the readings at the Near Position and at Far Positions A and B and adjust to zero if necessary.

When all readings are zero *without adjustment*, the laser plane is parallel to the surface.

Three Point Buck-In Procedure Using Multiple Targets

This method requires three targets. The procedure is basically the same as with one target, but it saves the time required to move a single target to the three different footprints.

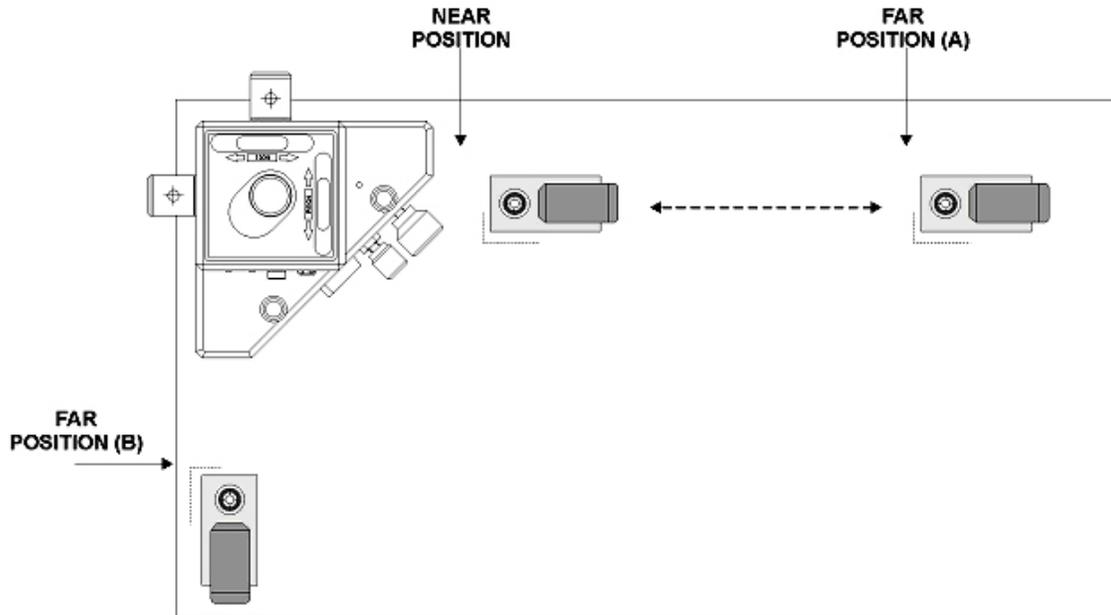


Figure 13 – Three Point Buck-in Using Multiple Targets

1. Zero all three targets on the near footprint.
2. Place two of the targets on the other two footprints.
3. Tilt or aim the laser until all three readouts read the same numbers and the same sign.
4. When all three readouts read the same, the laser plane is then parallel to all three points.

Two Point Buck-In (Straightness)

A laser beam is often used as a "straight edge" to measure straightness. Examples are machine tool ways or bore straightness measurement. The laser beam must be adjusted to be parallel to or coincident with an edge or centerline. The process of making that adjustment is called "bucking in." This section describes two types of buck-in methods: close (simple) and remote (more difficult).

Two points in space define a unique straight line; therefore, two reference points are needed in order to relate the position of a laser beam to a surface or centerline. Any two points may be chosen (the suitability of the points cannot be judged until after the measurement has been done). The points are usually selected near the extreme ends of the job for the sake of convenience. A Two Point Buck-In makes the laser beam parallel with these two points. It is best to place the laser source in a position that is as close to the near target position as possible. Orient the laser so that either the long axis of the base or the short axis of the base is parallel to the near and the far target positions.

Normal versus Remote Buck-In

There are two procedures for bucking in the laser, the close and the remote buck-in. The procedure used depends on the relationship of two distances: the distance between the laser unit and the first target, and the distance between the first and second targets. The normal buck-in is easier; the remote buck-in is useful in situations where the normal method would be nearly impossible.

Figure 14 illustrates the general rule for determining the buck-in method to use. L1 represents the distance from the laser to the first target. L2 represents the distance between the two targets. If L1 is less than one tenth of L2, the normal buck-in procedure is used. If L1 is greater than one tenth of L2, the remote buck-in procedure should be used. When in doubt, or if the close procedure is not producing good results, use the remote procedure.

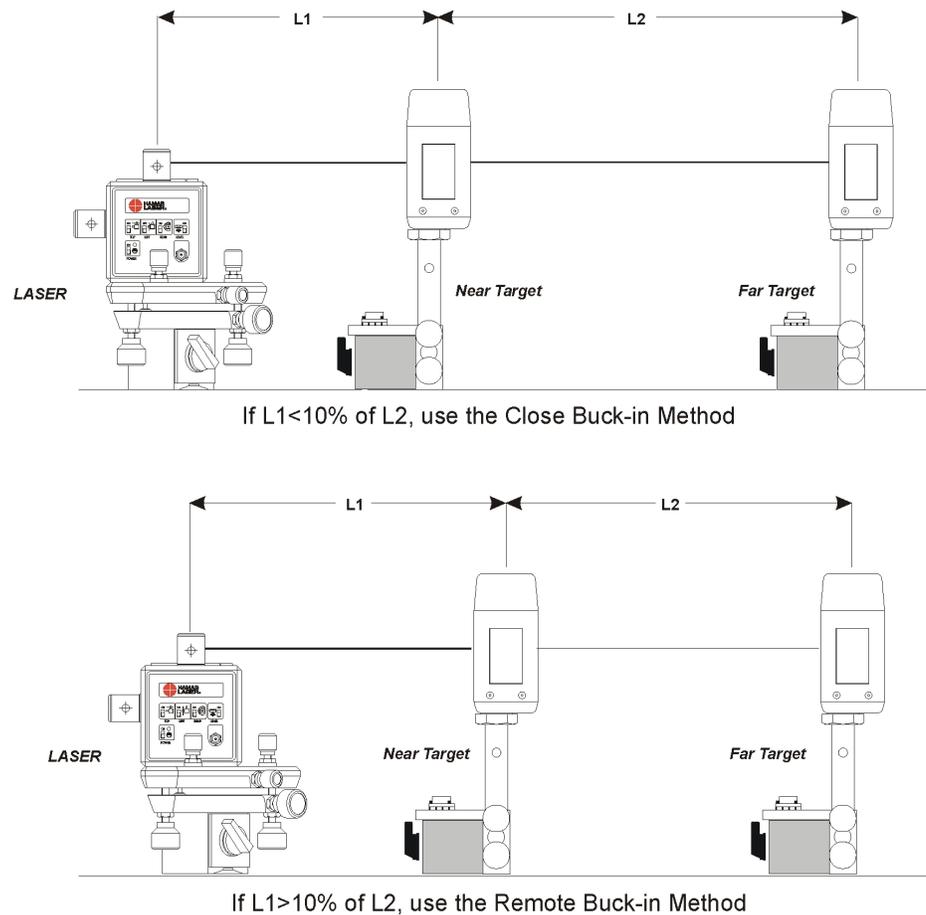


Figure 14 – Close vs. Remote Buck-in

Normal Buck-In

The normal buck-in procedure can be remembered by the rule, “Zero Near, Point Far.” Buck in the laser beam by zeroing it on the *near* target, and then “point” the laser beam using the appropriate adjustment knobs to *center* on the far target. The two steps are repeated until both targets show zero readings.

Remote Buck-In

As the distance between the laser and the near target increases with respect to the distance between the two targets, bucking in by the close method becomes nearly impossible. A special remote procedure has been developed for these situations. The remote buck-in uses simple geometry to make the laser beam parallel to the centerline of the two targets, and then centers the beam on that line. Figure 15 illustrates how the remote method works.

Unlike normal buck-in, where the laser is pointed *to* zero on the far target, the remote procedure has the laser point *through* zero to a point called the "set." The set distance is the offset between the parallel laser beam and the target centerline.

The uncorrected laser beam, the offset parallel beam and the set distance form a triangle. The uncorrected laser beam, the target centerline and the distance between the far target center and the far reading form a second triangle. The two triangles have the same three angles and are therefore geometrically identical (see Figure 16).

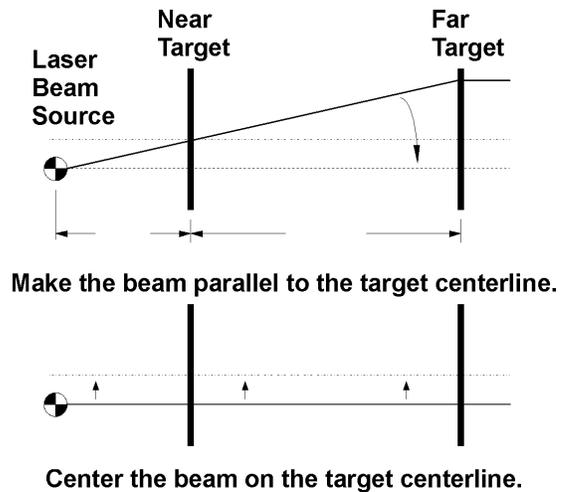


Figure 15 – Remote Buck-in

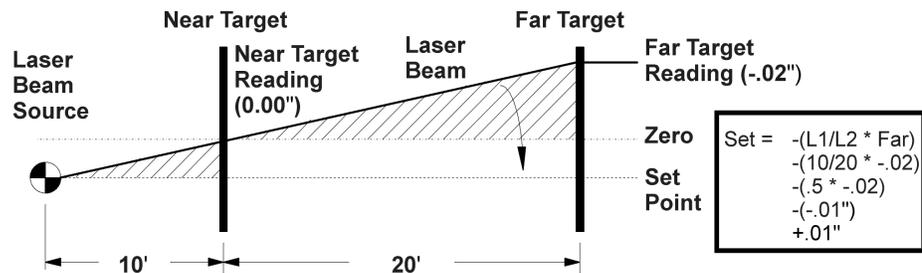


Figure 16 - Calculating the Set Point

A relationship between these two triangles can be stated in the formula, "The set is to L1 as the far reading is to L2." Stated mathematically, the ratio is $\text{Set}/L1 = \text{Far}/L2$. If L1, L2, and the far reading are known, the set can then be determined by the following formula: $\text{Set} = -(\text{Far reading} * L1/L2)$.

(Note: This is a simplified formula for cases where the laser beam is centered on the near target).

In remote buck-in, point *through* zero to the set point. This means moving the laser until it reads the set amount on the *other side* of zero from the starting point. In doing so, the sign of the number (negative or positive) will be reversed. Figure 16 illustrates this by taking sample readings and showing how the set point is derived. Notice the far reading is a negative number and the set point is positive as you go "through zero," resulting in a laser beam parallel to the target centerline, but offset by the set distance.

If the calculated set point exceeds the linear range of the target, (for example, the A-1519 target has a range of 1.0 in. or 25 mm) *the laser unit itself must be moved* by the set point amount. New measurements must then be retaken for both targets, and a new set calculated.

Figure 17 shows how to move the laser depending upon the sign of the calculated set point. **(Note:** If the laser is mounted on an L-106A screw lift stand, each full turn of the knob lifts or lowers the stand .125 in. or 3 mm).

Once the laser beam is parallel to but offset from the target centerline, center the beam on the near target. The targets should give the same reading, both number and sign, for both axes (horizontal and vertical). If not, refigure the set and buck in again. In most cases, remote buck-in can be accomplished in two or three passes. This method will work even when L1 is much greater than L2, or when the beam does not even hit the target (in such cases the far reading can be taken by using a ruler to measure the beam's distance from the target center).

The determining factor for which method to use can be summed up as follows:

- Use Normal Buck-in if the distance from the laser to the first target is less than one-tenth of the distance between the two targets. When using normal buck-in, the rule is: **Zero Near, Point Far**. Buck in the laser beam by zeroing it on the *near* target, and then "pointing" the laser beam using the appropriate adjustment knobs to *center* on the far target. The two steps are repeated until both targets show zero readings.
- Use Remote Buck-in if the distance from the laser to the first target is more than one-tenth of the distance between the two targets, or if normal buck-in method is not effective. When using remote buck-in, the rule is: **Point Through Zero to Set**. Zero the near target, determine the set point (making sure the sign is correct), and adjust the laser beam using the appropriate adjustment knobs to point to set rather than zero on the far target. Repeat if necessary, until both targets read zero. The laser beam is now bucked in to the reference points defined by the two targets.

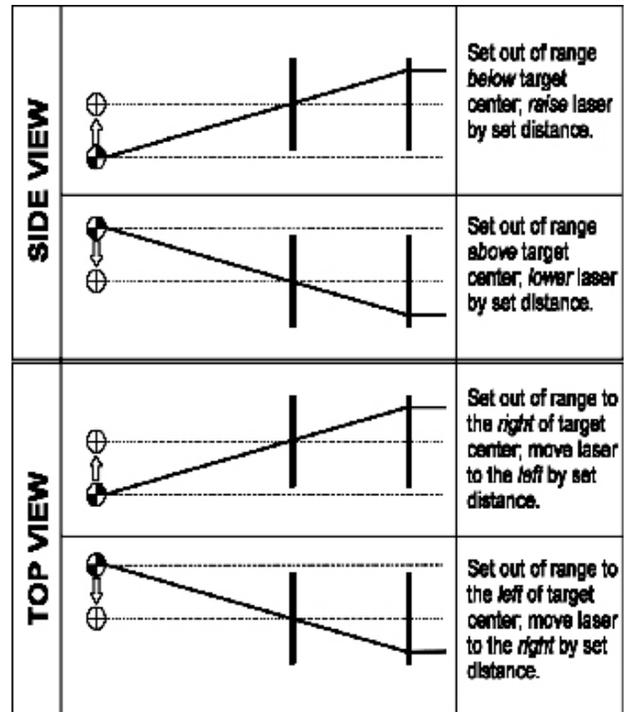


Figure 17 - Moving the laser when the set point is out of range of the target cell

Appendix A – Troubleshooting Guide

Problem		Possible Solutions
1	<i>Laser turret spinning and A-1519/1520 target not detecting laser (target LED not illuminated)</i>	<ul style="list-style-type: none"> • Power off laser and turn back on (all L-740 and L-730 series lasers have a power protection circuit that needs to be reset if a power surge causes the laser to turn off). • Turn off rotation of laser if the beam is OK and check target battery. • Check where beam is hitting target. If it hits too low, target will not turn on.
2	<i>Turret spinning; laser beam not on</i>	<ul style="list-style-type: none"> • Power off laser and turn back on. If the laser does not power on, it could be a blown laser diode. Return to HLI for repair.
3	<i>Laser beam on; turret not spinning</i>	<ul style="list-style-type: none"> • Ensure rotation switch is turned on. • Ensure rotation speed knob is turned up. • Check batteries – if the battery is low, there may not be enough voltage to spin the turret, but the laser may still be visible. • Environment is too cold. Laser cannot be used below 32° F (0° C). • Belt drive may be broken. Return to HLI repair.
4	<i>Laser not spinning and no laser beam</i>	<ul style="list-style-type: none"> • Ensure power supply is connected. • Replace batteries in the battery pack. • Check power supply connector. Widen split in pin inside the female connector on the laser with a small screwdriver. • Check A/C power source. Use second A/C power supply if available.
5	<i>Noisy target (A-1519/1520) readings on PDA</i>	<ul style="list-style-type: none"> • NOTE: On average the user can expect .00002 in/ft to .00005 in/ft (0.0025 mm/m- 0.004 mm/m) of noise in good operating conditions. • Check for vibration in laser instrument stand (tripod) or surface the laser is sitting on. If laser is mounted on a machine tool, try turning machine tool off. • For very noisy readings, check for rotary lights (like on fork lift) or strobe lights (this will look like a “laser” to the target). • Check for air turbulence – air conditioning vents right over target? Check for open doors in summer or winter. See manual for Atmospheric Conditions. • Check for reflections from metal surfaces by turning off the rotation of the laser and slowly rotating it by hand to look for reflections—dim overhead lights if possible. • Check for excess background light (use light shields). A warning may pop up on PDA display. • Ensure only one laser is hitting the target at a time. Turn off other laser plane rotation to see if this helps. • Ensure the target is facing/pointing directly at the laser (within ±5 degrees). • Check light frequency (50 Hz vs. 60 Hz for background light). For correction feature of A-1519/1520 targets, see Target Utility Manual. North & South America is 60 Hz. Europe, Australia and parts of Asia are 50 Hz. • If PDA is plugged in, try unplugging PDA from A/C adapter. • Check for possible radio interference.

<p>6</p>	<p>No target readings in PDA. Target LEDs illuminated (means target is detecting laser)</p> 	<ul style="list-style-type: none"> • Check Zigbee radio communication. There should be 2 green LED lights in PDA boot, (1) solid, (1) blinking. If no lights, hold green power button down for three seconds and release, restart PDA and tap Cancel on Unidentified USB Device Pop-up. • Check Radio Receiver battery – plug in A/C adapter to ensure it has power. • Ensure the check box to the left of the display window in Read15 (see manual) is checked for each target. • Ensure channel setting (system ID) on A-1519/1520 matches the setting in PDA – See Read15 Manual. • Ensure Target ID on A-1519/1520 is set to 1-4 for first screen or 5-8 in second screen in Read15. • Target is too close to laser (target LEDs blink). • Check for reflections. • Check for strobe lights and rotary lights. • Check for excess background light (normally target LEDs blink) • Plug target into computer via USB cable and open Target Utility software. If software shows reading, then there is probably a problem with the radio. • Ensure PDA has same radio frequency as Target (900 MHz or 2.4 GHz) • Hit reset switch on target (use paper clip in hole near Target ID/Channel Selector Panel). • Laser could be hitting too low or high on target window (it should be near the window). It is possible for the laser to activate the auto wake up feature of target, but not enough of the beam is hitting the PSD (target sensor) to get a reading.
<p>7</p>	<p>No target readings in software. Target LED illuminated</p>	<ul style="list-style-type: none"> • Ensure A-910 radio base station is connected to USB port. • Ensure the correct COM port is selected for the USB bridge controller – see Windows Device Manager (has to be lower than COM10). • Check Device Manager in Windows Control Panel. Set COM port for USB bridge controller lower than COM10. • Ensure the correct target ID is chosen in Machine Tool Geometry or Read8 software. • Ensure channel setting (system ID) on A-1519/1520 matches the setting in A-910 (see the Target Utility Manual). • Ensure SND/RC LEDs on A-910 are blinking (see the Target Utility Manual). • Ensure ACTUAL TARGETS (RADIO in Plane5) is selected in Read8, Plane5 or Machine Tool Geometry software. • Ensure antenna is connected to A-910. • Target may be too close to laser (target LED's blink). • Check for excess background light (normally target LEDs blink). • Ensure A-910 radio base station has same radio frequency as target (900 MHz or 2.4 GHz). • Laser could be hitting too low or high on target window (it should be near the window). It's possible for the laser to activate the auto wake up feature of target, but not enough of the beam is hitting the PSD (target sensor) to get a reading.

8	<i>Target LEDs Blink – Laser Beam OK and Rotating</i>	<ul style="list-style-type: none"> • Check for reflections. • Check for strobe lights and rotary lights. • Check for excess background light (normally target LEDs blink). • Ensure the beam is not being clipped by an obstruction or not on the edge (upper or lower) of the PSD sensor. • Laser rotation may be too slow. • Make sure two lasers are not sweeping across the target. • Make sure target is facing the laser within ± 5 degrees. • Reset target (use paper clip in hole near Target ID/Channel Selector Panel).
9	<i>“OFF TGT” shown in target display – PDA</i>	<ul style="list-style-type: none"> • Radio communication is working, but the target does not “see” the laser. <ul style="list-style-type: none"> ▪ Ensure laser beam is not blocked. ▪ Ensure laser beam is bright. ▪ Check laser power supply, especially if using a battery pack.
10	<i>Cannot see level vials</i>	<ul style="list-style-type: none"> • Turn on level light switch. • Turn on master power switch. • Check power supply connection.
11	<i>“Runtime Error” in software</i>	<ul style="list-style-type: none"> • Do not unplug the A-910 from the USB port while still using the program. • Report to HLI the exact key strokes that created the Runtime Error.
12	<i>Software crashes upon loading</i>	<ul style="list-style-type: none"> • Ensure USB/Serial Converter cable is connected to the laptop’s USB port. If problem persists, contact HLI.
13	<i>PDA locks up</i>	<ul style="list-style-type: none"> • Hit RESET switch <ul style="list-style-type: none"> • Nomad PDA – Hold green POWER button down for 3 seconds and release. Tap RESTART on the power menu. ▪ Dell PDA – RESET is on right hand side of the back of PDA, near the lower right corner of the radio module. ▪ HP IPAQ – RESET is on bottom end of PDA.
14	<i>PDA turns off automatically</i>	<ul style="list-style-type: none"> • Check the Power Saving Options in the PDA (see PDA manual for details).
15	<i>PDA is frozen</i>	<ul style="list-style-type: none"> • Check the lock switch on the side of the PDA. If that does not work, press RESET.
16	<i>Nomad PDA – no communication</i>	<ul style="list-style-type: none"> • Check Zigbee radio communication. There should be 2 green LED lights in top PDA boot (1 solid, 1 blinking). If there are no lights, hold the green power button down for three seconds and release. Restart PDA and tap CANCEL on Unidentified USB Device pop-up.

Appendix B – Equipment Drawings

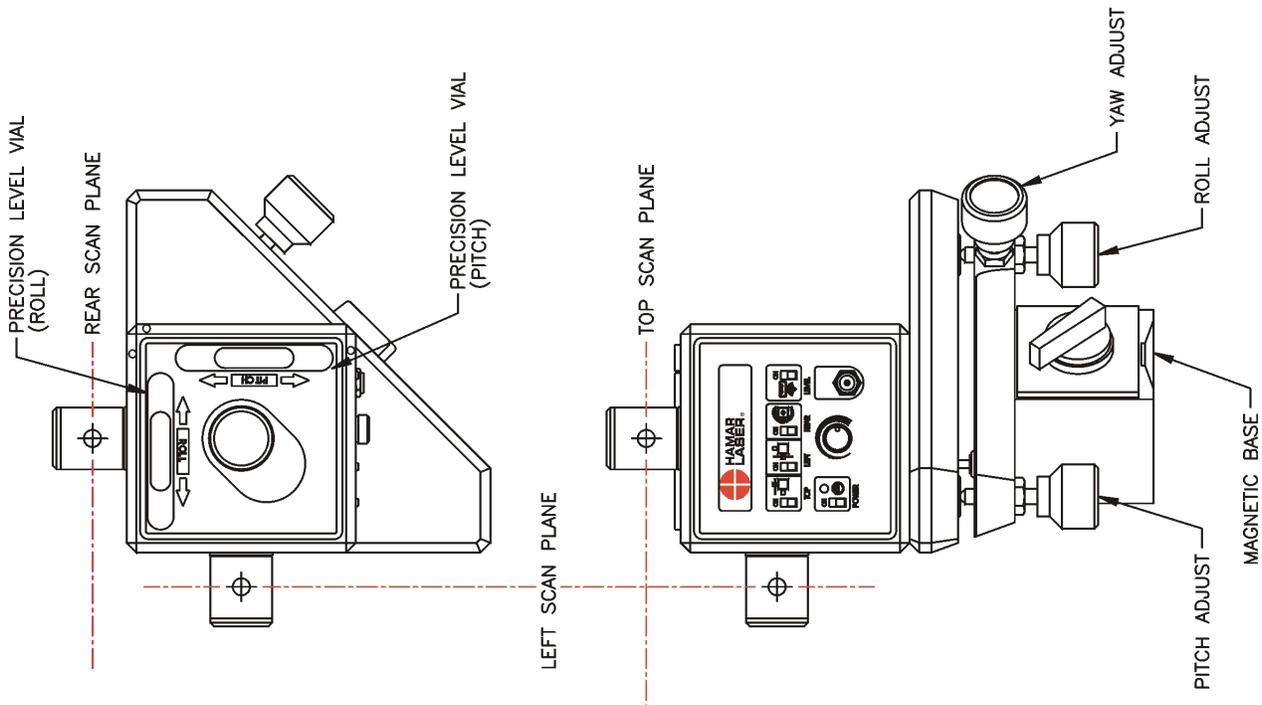
L-733 Precision Geometry Laser

SPECIFICATIONS L-733 TRIPLE SCAN LASER WITH L-126 COARSE ADJUST BASE

Weight	Laser: 3 lbs [1.3 kg] Base: 4.8 lbs [2.2 kg] Battery Pack: 1 lb [0.45 kg]
Material	Laser: Aluminum and Stainless Steel Base: Aluminum
Laser Type	Class II Visible Diode, 670 nm Wavelength (Class I in Scanning Mode); .160" [4.06 mm] Beam Diameter
Beam Power	.09 mW per Straight Beam
Beam Stability	.0001"/hr/F [.005 mm/hr/C], Translational 0.2 arc sec/hr/F [0.36 arc sec/hr/C] Angular
Beam Straightness	10 microinch/ft, ±.0001 Air Noise
Beam/Plane Flatness	30 uin/ft [2.5 u/M] Plus Maximum Translational Error of ±.0002" [5.0 u] 360° Sweep, 10 uin/ft [0.8 u/M] Plus Maximum Translational Error of ±.0002" [5.0 u] 90° Sweep
Beam/Plane Squareness	3 Beams Mutually Square to within 1.0 arc sec 3 Planes Mutually Square to within 1.0 arc sec
Mechanical Parallelism/Squareness	Top Scan Plane (Top Turret) Parallel to Base within .0003"/ft [0.025 mm/M], Top and Bottom Mounting Feet Parallel within .0002"/ft [0.017 mm/M], Side and Bottom Mounting Feet Square within .0004"/ft [0.033 mm/M]
Operating Modes	1, 2, or 3 Beams and/or 1, 2, or 3 Scanned Planes in Any Combination, Individually Switched
Power Supply	9 VDC External Battery Pack (4 Cells)
Power Draw	(See Chart)
Coarse Range	±1.5°
Fine Resolution	.0001" Fine Adjustment = 0.17 arc sec (.001"/100 ft)

POWER DRAW	LASER ONLY	LASER & SCANNER	BATTERY LIFE*
1 Beam	130 mA	130 mA	2.5 hrs
2 Beams	180 mA	230 mA	1.4 hrs
3 Beams	260 mA	330 mA	1.0 hrs

* Per 9V alkaline battery (500 mAh). Multiple battery life based on the number of batteries used (external battery pack uses 4 cells).



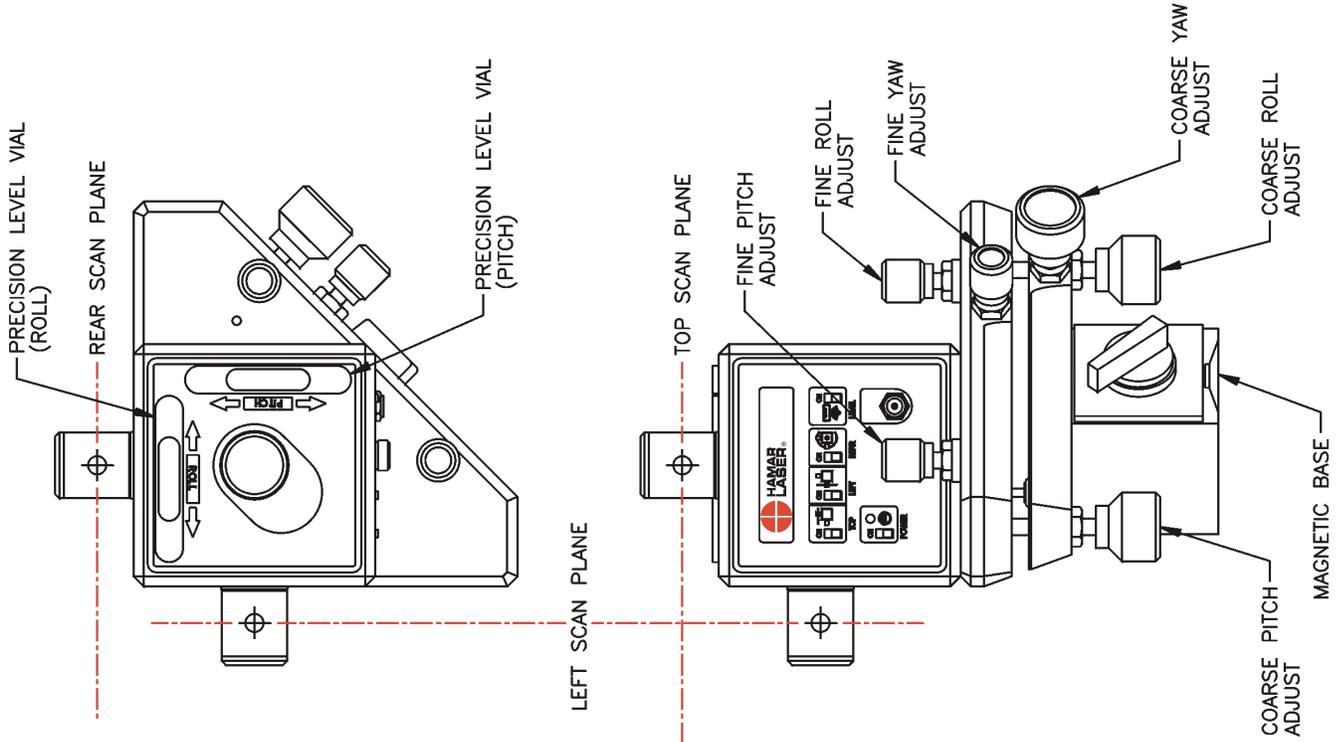
L-743 Ultra-Precision Geometry Laser

SPECIFICATIONS L-743 TRIPLE SCAN LASER WITH L-127 COARSE/FINE ADJUST BASE

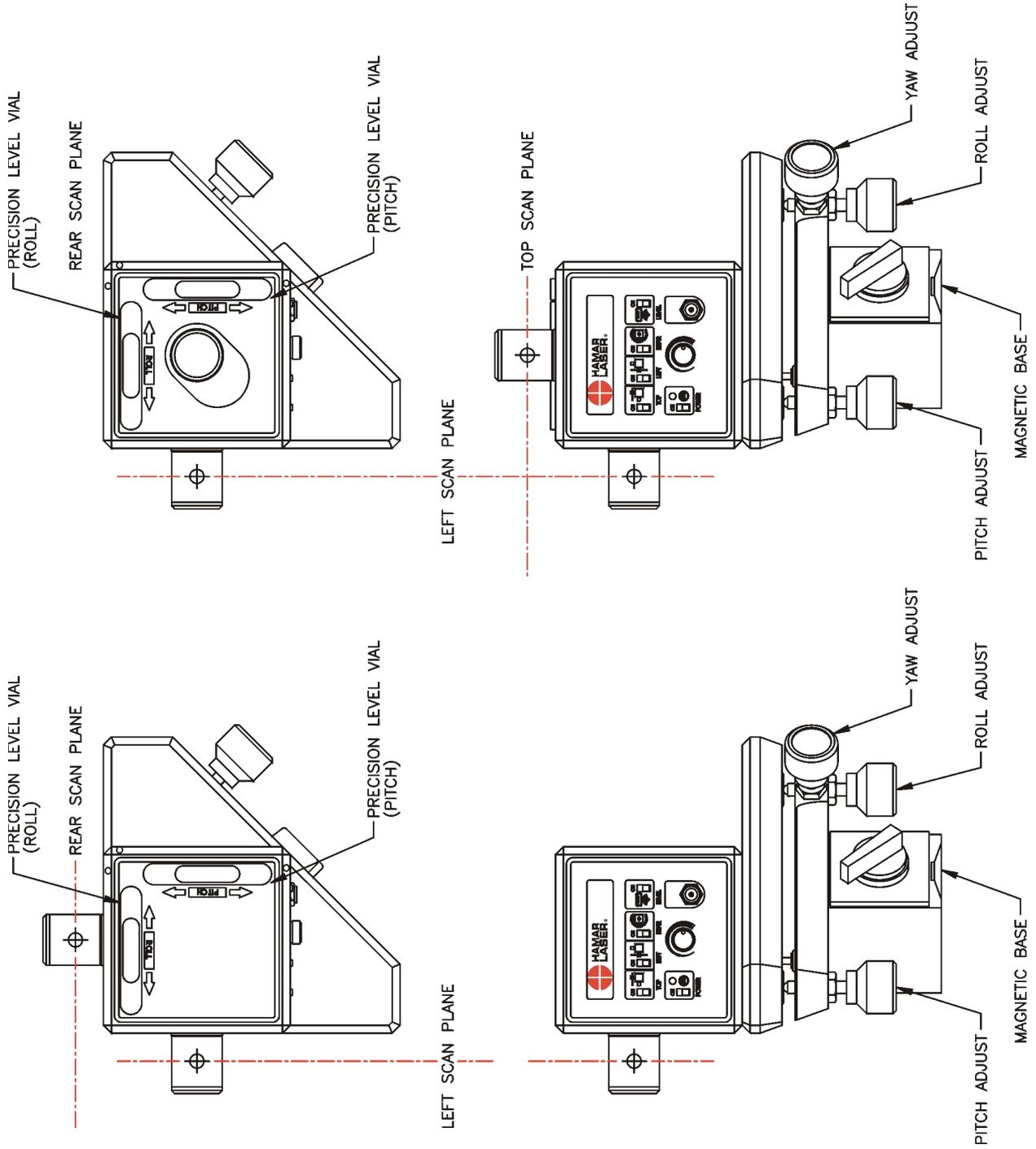
Weight	Laser: 3 lbs [1.3 kg] Base: 4.8 lbs [2.2 kg] Battery Pack: 1 lb [0.45 kg]
Material	Laser: Aluminum and Stainless Steel Base: Aluminum
Laser Type	Class II Visible Diode, 670 nm Wavelength (Class I in Scanning Mode); $\cdot 160''$ [4.06 mm] Beam Diameter
Beam Power	$\cdot 09$ mW per Straight Beam
Beam Stability	$\cdot 0001''/hr/F$ [$\cdot 005$ mm/hr/C] Translational 0.2 arc sec/hr/F [0.36 arc sec/hr/C] Angular
Beam Straightness	10 microinch/ft, $\pm \cdot 0001$ Air Noise
Beam/Plane Flatness	30 μ in/ft [2.5 μ /M] Plus Maximum Translational Error of $\pm \cdot 0002''$ [5.0 μ] 360° Sweep, 10 μ in/ft [0.8 μ /M] Plus Maximum Translational Error of $\pm \cdot 0002''$ [5.0 μ] 90° Sweep
Beam/Plane Squareness	3 Beams Mutually Square to within 1.0 arc sec 3 Planes Mutually Square to within 1.0 arc sec
Mechanical Parallelism/Squareness	Top Scan Plane (Top Turret) Parallel to Base within $\cdot 0003''/ft$ [0.025 mm/M], Top and Bottom Mounting Feet Parallel within $\cdot 0002''/ft$ [0.017 mm/M], Side and Bottom Mounting Feet Square within $\cdot 0004''/ft$ [0.033 mm/M]
Operating Modes	1, 2, or 3 Beams and/or 1, 2, or 3 Scanned Planes in Any Combination, Individually Switched
Power Supply	9 VDC External Battery Pack (4 Cells)
Power Draw	115 VAC Adapter (See Chart)
Course Range	$\pm 1.5'$
Fine Resolution	$\cdot 0001''$ Fine Adjustment = 0.17 arc sec ($\cdot 001''/100$ ft)

POWER DRAW	LASER ONLY	LASER & SCANNER	BATTERY LIFE*
1 Beam	100 mA	130 mA	2.5 hrs
2 Beams	180 mA	230 mA	1.4 hrs
3 Beams	260 mA	330 mA	1.0 hrs

* The 9V alkaline battery (500 mAh), multiply battery life figure by the number of batteries used (external battery pack uses 4 cells).



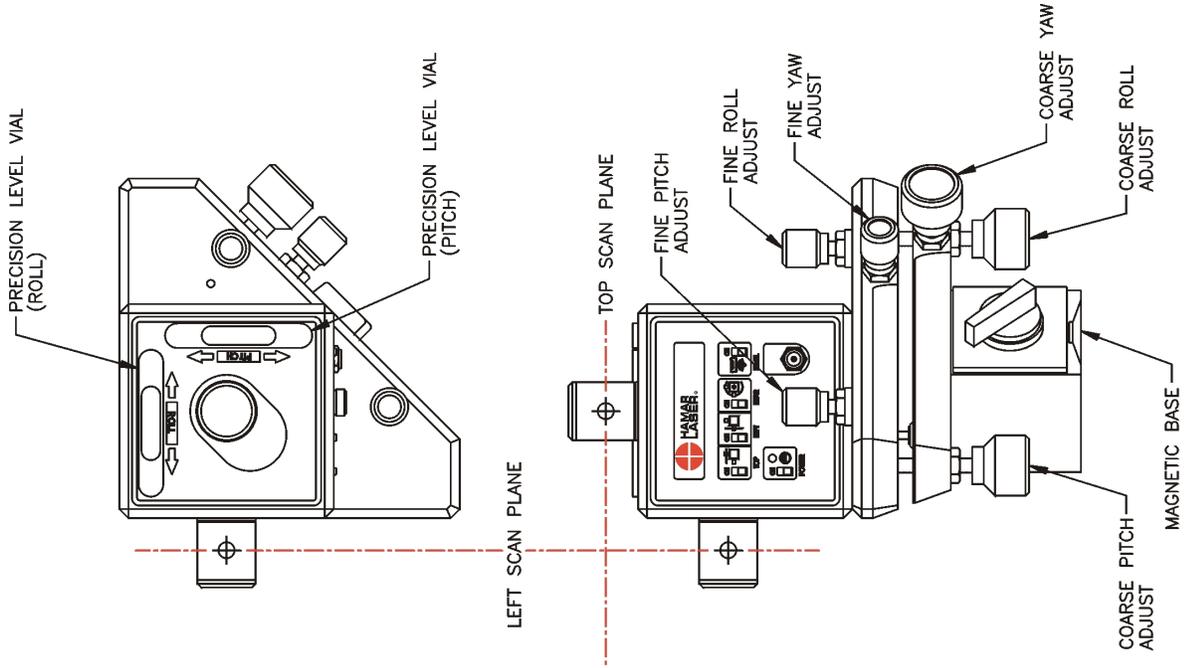
The L-732 Dual Scan Precision Roll Alignment Laser



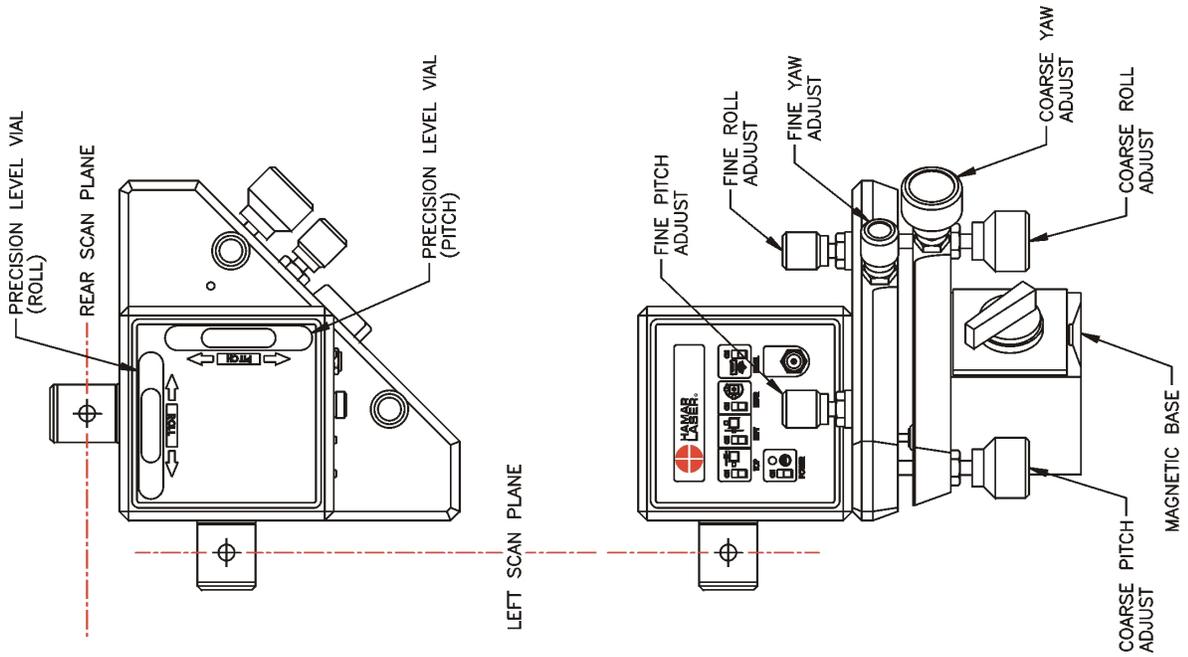
L-732 (Ceiling/Wall Configuration)

L-732 (Wall/Wall Configuration)

The L-742 Dual Scan Ultra-Precision Roll Alignment Laser



L-742 (Ceiling/Wall Configuration)



L-742 (Wall/Wall Configuration)

Appendix C – Interpreting the A-1519/1520 Type II Calibration Reports

The A-1519-2.4 Target has a 0.5 micron resolution and 3.5 micron accuracy, versus the A-1520-2.4 Target, which has a 0.25 micron resolution and 1.5 micron accuracy. When the elevation of either target is set near zero (within ± 1 mm from zero), the most accurate part of the sensor is in use. The calibration graph on Page 32 shows that the error in the central part of the sensor for the A-1519-2.4 is less than 1 micron, which is better than the total error of the A-1520-2.4 (± 1.5 microns). Furthermore, when a target is zeroed on a given spot on the sensor for high-accuracy measurements (for example, measurement deviations of less than 25 microns), the error in the measurement from one point to the next is extremely small.

When a target is calibrated, measurements are taken every 1 mm and the error in between is interpolated. This makes it very likely that the error in measurement at the point where the target is zeroed is nearly identical to the error in each subsequent measurement because the difference in sensor area between the two points is less than 1 mm. In effect the error really does not matter – it’s like having the same error “offset” at each point. The errors start becoming important only when large deviations from zero are being measured, for example 1 mm or more.

The accuracy of the A-1519/A-1520 Type II targets is specified in the report below as an error of 3.2 microns (μm). This means that the maximum error of a given measurement could be $\pm 3.2 \mu\text{m}$ over the central 80 percent of the measuring area of the target.

For example, if one measurement point was at -12.5 mm (-.492 in.) and the next measurement point was +12.5 mm (+.492), then the maximum error in the 25 mm deviation would be no more than 6.4 μm (.00024 in.).

When measuring small deviations in flatness/straightness (less than .1 mm), the maximum error is much lower (usually about 1 micron or better). See the explanation of the graph below for more details.

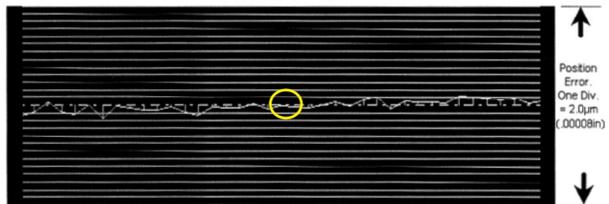
HAMAR LASER INSTRUMENTS, INC - UniTarget® Calibration Certificate / Report

SERIAL NUMBER: **19-10499**
 Calibration Date: 12/3/2007

Position Detector Length (mm):	30.0 mm
Position Detector, Calibrated Range (mm)	± 12.7 mm
Output Resolution (microns)	0.5 μm
Accuracy Spec (Within Calibrated Range)	3.8 μm , 0.00015 inches
Calibrated (measured) accuracy *	3.3 μm, 0.00013 inches

NOTE: This device complies with Hamar Laser specifications as of the date of this certificate. Hamar Laser reserves the right to make future improvements and change specifications without notice. Calibration Reference: Interferometer SN:G24358, Cal Cert #G24358-121206/1. Exp Date: Dec 2009

*Maximum error, within the central 80% of the position detector area.
 3.3 μm , 0.00033 mm, 0.00013 inches
 Linear Fit (Least Sqrs): Slope=0.19750 $\mu\text{m}/\text{mm}$



* NOTE: CALIBRATED WITH MASTER LASER #719-001

Target Temperature: 29.9 - 29.8°C
 Ambient Temperature: 21.1 - 21.1°C
 Relative Humidity: 25.8 - 25.8%
 Barometric Pressure: 981 - 980 mBar
 Dampening (n Samples): 10

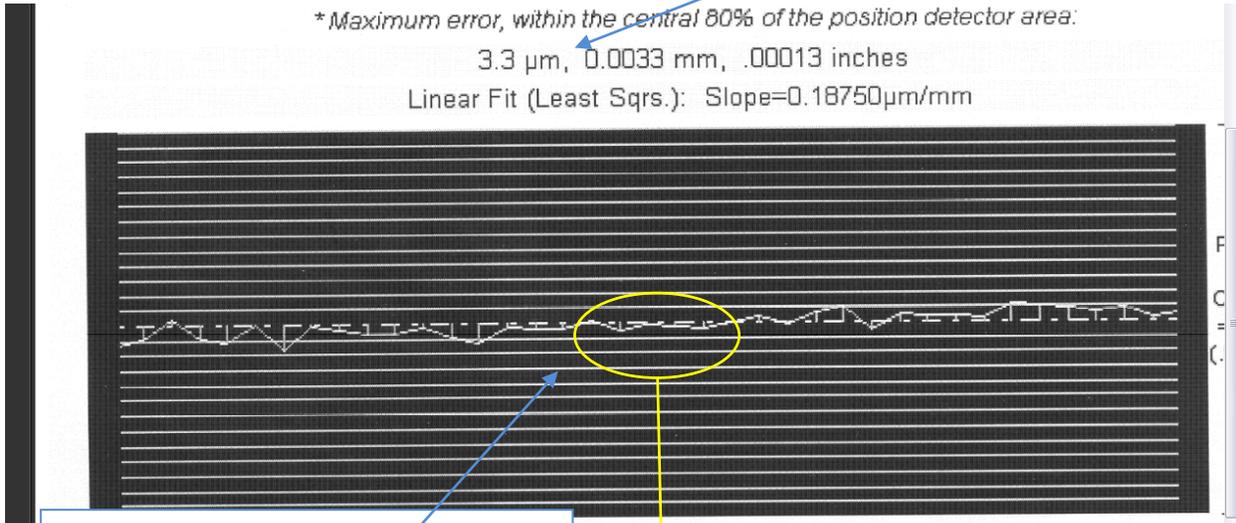
File: H:\MFG_SOFT\UniTarget\Calib\Verify\SN10499-DEV10 12-3-2007 11(1).dat, Temp. drift - 0.1°C, E7=10

Total Error = +/- 3.3 microns

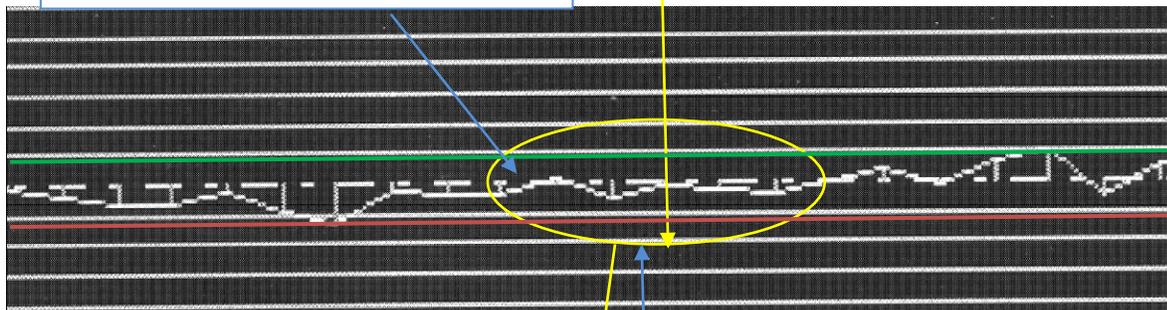
* Maximum error, within the central 80% of the position detector area:

3.3 μm , 0.0033 mm, .00013 inches

Linear Fit (Least Sqs.): Slope=0.18750 $\mu\text{m}/\text{mm}$



Approx. +/- 4 mm of measuring area – each vertical line on the graph equals 1 mm.

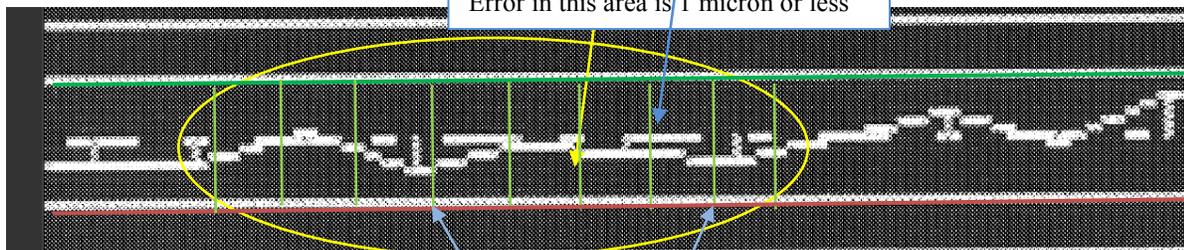


+ 2 microns

0.000

- 2 microns

Error in this area is 1 micron or less



+ 2 microns

0.000

- 2 microns

Each green vertical line equals 1 mm of measuring area on the detector. The total area here is 8 mm.

Appendix D – Care and Cleaning of Target Optics

The proper care and cleaning of optical windows and/or lenses of Hamar Laser’s position-sensing devices (targets) assures optimum performance. Contaminants on an optical surface increase scatter, absorb laser energy, and eventually degrade the accuracy of the position-sensing devices. Because cleaning any precision optic risks damaging the surface, optics should only be cleaned when absolutely necessary. When cleaning is required, we recommend the following supplies and procedures.

Required Supplies

- **Optics Cleaning Tissue:** Soft, absorbent, lint-free lens tissue
- **Swabs:** Cotton swabs with wooden handles or polyester swabs with polypropylene handles
- **Dust Blower:** Filtered dry nitrogen blown through an antistatic nozzle is best. Canned dusters, such as Dust-Off, will also work.
- **Mild Soap solution:** Neutral soap, 1 percent in distilled water. Avoid scented, alkali, or colored soap such as liquid dishwashing detergents or hand soap. Ten drops of green soap (available at a pharmacies and optical cleaning suppliers) per 100 cc of distilled water is an acceptable alternative.
- **Isopropyl Alcohol:** Spectroscopic grade. Over-the-counter alcohol contains too much water and may have impurities.
- **Acetone:** Spectroscopic grade. Do not use over-the-counter Acetone, such as the type intended for nail polish removal.

NOTE: *When cleaning precision optics, even with the best quality optical cleaning tissue, use gentle pressure to avoid scratching the surface or damaging the optical coating(s). Always wipe using a figure-eight motion in one direction (begin at the top and work toward the bottom in a figure-eight motion). Use only moistened (not soaked) optical cleaning tissue, Swabs and Spectroscopic grade Acetone and Isopropyl Alcohol. Never spray any type of liquid directly on the device or submerge any part of the device.*

Removing Dust

Dust can bind to optics by static electricity. Blowing only removes some of the dirt. The remainder can be collected by using wet alcohol and Acetone swabs wrapped with optical lens tissue. Acetone dries rapidly and helps to eliminate streaks.

1. Blow off dust.
2. If any dust remains, twist lens tissue around a cotton swab moistened in alcohol and repeat as necessary.
3. Repeat using Acetone.

Cleaning Heavy Contamination

Fingerprints, oil, or water spots should be cleaned immediately. Skin acids attack coatings and glass and can leave permanent stains. Cleaning with solvents alone tends to redistribute grime.

1. Blow off dust.
2. Using a soap-saturated lens tissue around a swab, wipe the optic gently. Repeat as necessary.
3. Repeat using a distilled water-saturated lens tissue wrapped around a swab.
4. Repeat using an alcohol-saturated lens tissue wrapped around a swab.
5. Repeat using an acetone-saturated lens tissue wrapped around a swab.