LASER MEASUREMENT SYSTEM

5526A

OPERATOR HANDBOOK SUPPLEMENT

FOR

STRAIGHTNESS INTERFEROMETERS

5526A OPTIONS 030, 031, and 032

This handbook supplement applies directly to Hewlett-Packard Model 10690A and 10691A Straightness Interferometers, and to 10579A Straightness Adapters with 10579-60004 Resolution Extenders having the Serial Prefix 1328A. For later revisions, a change sheet is included with this supplement.

5301 STEVENS CREEK BLVD., SANTA CLARA, CALIF. 95050
Printed: NOV 1973

Manual Part No. 05526-90022
Microfiche Part No. 05526-90024

PRINTED IN U.S.A.

HEWLETT hp PACKARD

SAFETY PRECAUTIONS

WARNING

LASER BEAM

This instrument emits laser light. The power output of the HP laser is low in comparison to most other lasers, either continuous wave or pulsed, but due to the high brilliance factor, the output beam of any laser should never be allowed to strike the eye directly. It is the considered opinion of Hewlett-Packard Company that the light beam from this device presents NO hazard to health and safety. However, the existence of newly enacted federal regulations with respect to laser devices together with the lack of any widely accepted standards of laser power safety thresholds requires the insertion of this cautionary statement.

WARNING

HIGH VOLTAGE

High voltages are generated within the laser housing. The cover of the Model 5500C Laser is provided with an interlock to prevent accidental access to these voltages. There are no high voltages on the interconnecting cable however, should it become cut or disconnected.

CAUTION

The Straightness Interferometer and Straightness Reflector have precision ground and accurately lapped external surfaces. For best performance, keep the mechanical and optical surfaces clean.

INTRODUCTION

This publication is a supplement to the basic 5526A Laser Measurement System Operator's Handbook, and should be placed in the Operator's Handbook three-ring binder. Model 5526A Options 030 and 031 provide the capability of making straightness measurements over the ranges of 4 inches (100 mm) to 10 feet (3m) and 3 feet (1m) to 100 feet (30m) respectively. Option 032 is the combination of Options 030 and 031; it provides a straightness measurement capability over both ranges.

The basic 5526A Laser Measurement System includes the following items:

- 5500C Laser Head
- 5505A Laser Display

The straightness measurement options consist of the following items:

Option 030 Short-Range Straightness Interferometer

- 10579A Straightness Adapter
- 10690A Short-Range Straightness Interferometer

Option 031 Long-Range Straightness Interferometer

- 10579A Straightness Adapter
- 10691A Long-Range Straightness Interferometer

Option 032 Full-Range Straightness Interferometer

- 10579A Straightness Adapter
- 10690A Short-Range Straightness Interferometer
- 10691A Long-Range Straightness Interferometer

As shown in Figure 1, the 10579A Straightness Adapter consists of the 10579-60004 Resolution Extender and the 10579-60001 Straightness Adapter Assembly. Figure 2 shows a typical Straightness Interferometer. The only difference in the short-range and long-range versions is in the optical characteristics. Each Straightness Interferometer consists of a Straightness Interferometer Assembly and a Straightness Reflector.

The Straightness Interferometer measures lateral displacement between the Straightness Interferometer Assembly and the Straightness Reflector mirror axis. Displacement is measured along a line perpendicular to the reflecting mirror axis and parallel to the longer dimension of the reflecting mirrors. A single pass measures deviation in one plane. If passes are made in both the horizontal and vertical planes, then the total deviation from a straight line can be determined.

The Straightness Interferometer differs from the distance measuring interferometer in that the returned laser beam travels along the same axis as the transmitted laser beam. For this reason, it is necessary to place the 10579-60001 Straightness Adapter Assembly between the Laser Head and the Straightness Interferometer Assembly. The adapter displaces the returned beam to an axis one-half inch below the transmitted beam, and the return beam enters the lower DISPLAY A aperture on the Laser Head turret.

NOTE

If the 5500C Laser Head is to be used primarily for straightness measurements, the 10579-60001 Straightness Adapter Assembly may be installed inside the laser head. Otherwise, the Laser Head can be modified to permit rapid installation on the front of the Laser Head. The adapter can then be installed and removed without the use of tools.

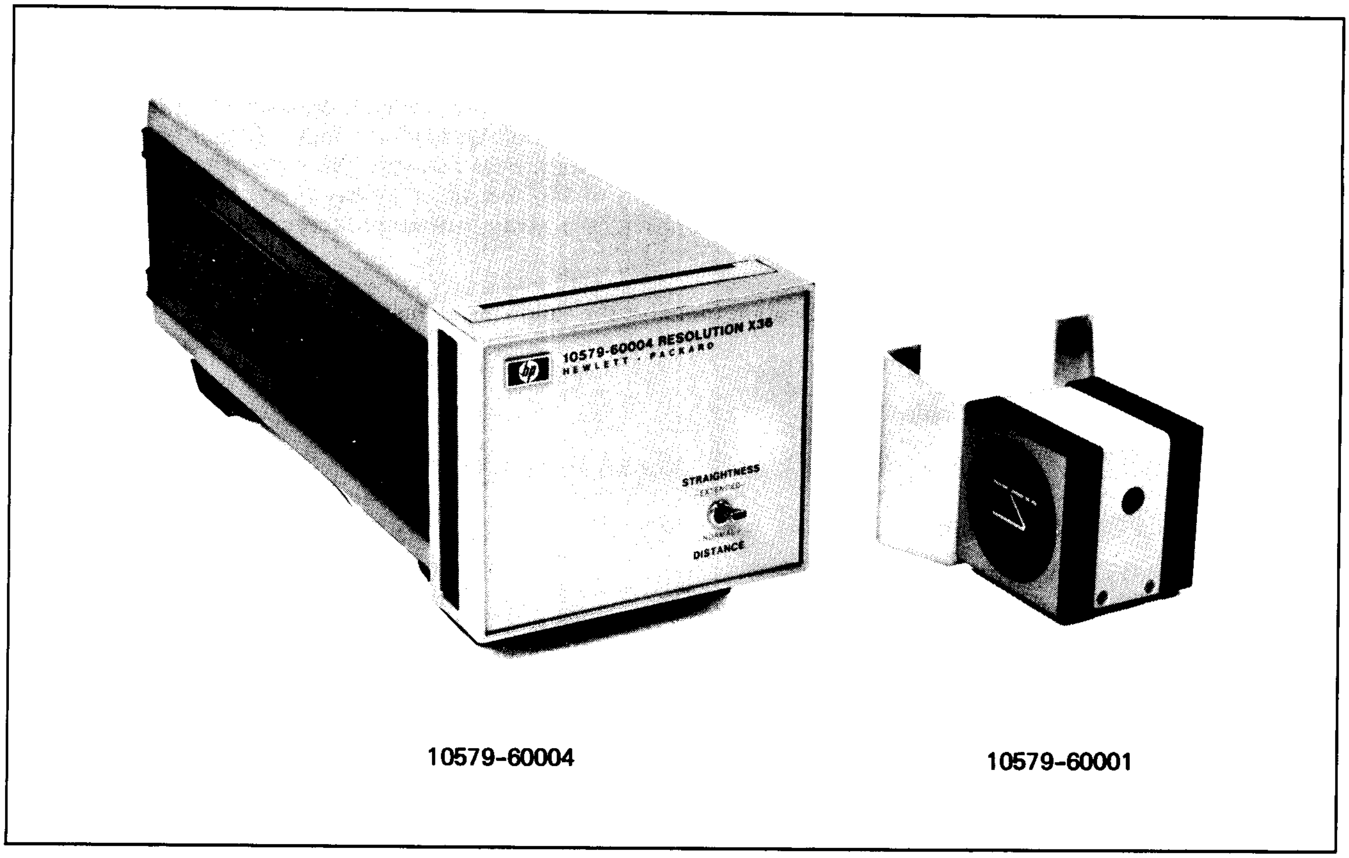


Figure 1. 10579A Straightness Adapter

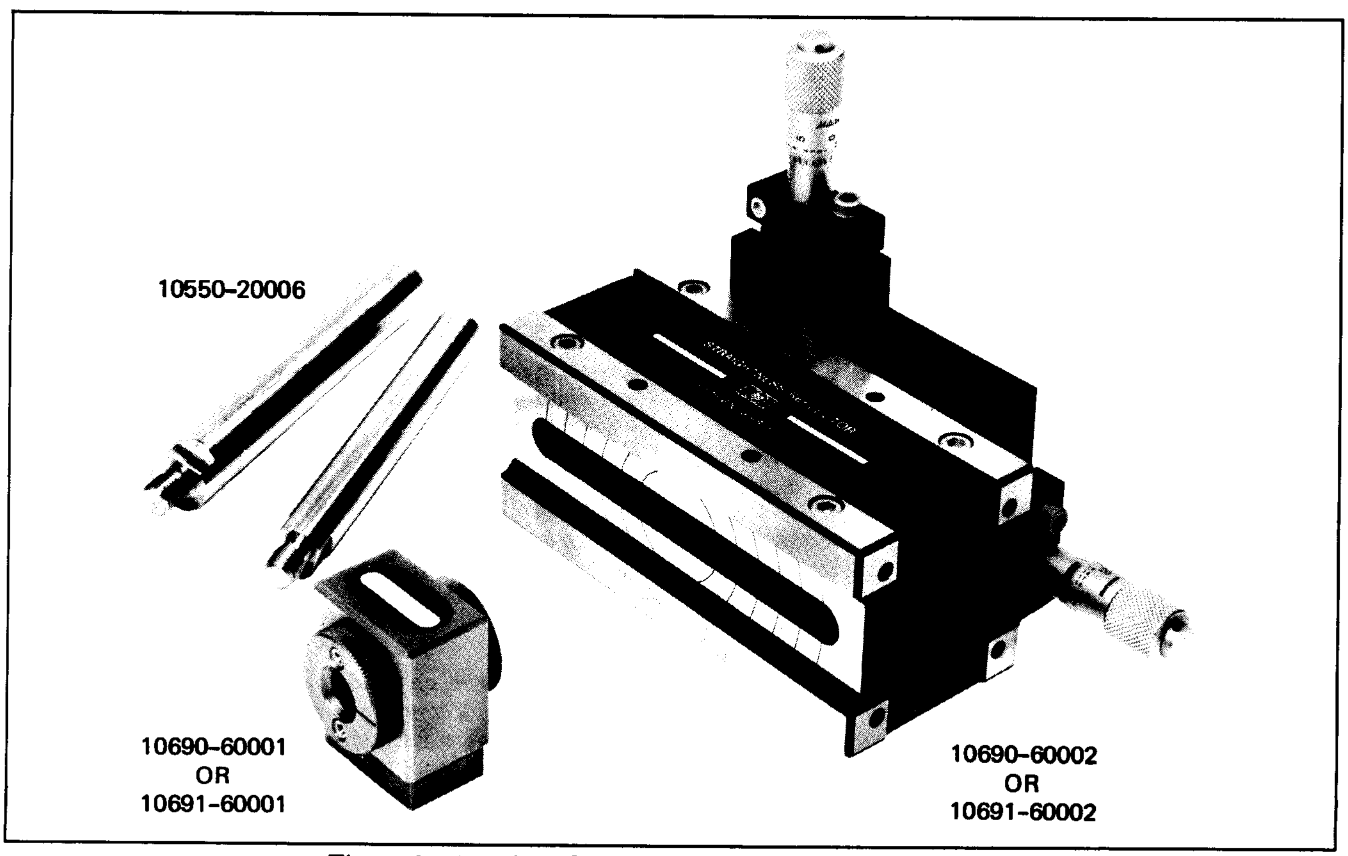


Figure 2. 10690A and 10691A Straightness Interferometers

5526A LASER MEASUREMENT SYSTEM AND ITS PUBLICATIONS

The 5526A Laser Measurement System is described in the 5526A Laser Measurement System Operator's Handbook and each standard option is described in a separate publication. A list of publications about the laser measurement system is available from the following address:

HEWLETT-PACKARD
5301 Stevens Creek Boulevard
Santa Clara, California 95050
United States of America
Attention: Laser Publications

FIRST TEST OF 5526A OPTION 30 SERIES STRAIGHTNESS INTERFEROMETERS

When the 5526A Laser Measurement System with Options 030, 031, or 032 is first delivered and set up for use, it should be tested for correct operation. Refer to the 5526A Laser Measurement System Operator's Handbook for basic system tests. For the first operational test with the Straightness Interferometer options refer to the following paragraphs.

Operational Test

An operational test is normally performed on a machine having a table that is movable in one or more axes, and the following procedure is based upon a machine installation. If a machine is not available, the setup can be simulated on a stable flat surface. Place the 5500C Laser Head, 10579-60004 Resolution Extender, and 5505A Laser Display in suitable operating positions and complete the following procedure. It is recommended that the Laser Head be mounted on a 10580A Laser Tripod.

CAUTION

Electrical power must be off while connecting or disconnecting cables in the Laser Measurement System.

1. Connect 05500-60025 cable between DISPLAY A connector or rear of 5500C Laser Head and LASER connector on rear of 10579-60004 Resolution Extender.

2. Connect second 05500-60025 cable between DISPLAY connector on rear panel of 10579-60004 Resolution Extender and LASER connector on rear panel of 5505A Laser Display.

3. Connect power cord between 5505A Laser Display and a suitable outlet.

4. Turn system power on and set Resolution Extender for the STRAIGHTNESS (EXTENDED) mode.

5. Set up and align the Straightness Interferometer optical system. (Refer to Optical System Alignment on page 13.)

6. With 5505A Laser Display BEAM ALIGNMENT meter indicating in the green range, press the RESET switch and verify that the RESET lamp stops flashing.

7. Momentarily interrupt the laser beam and verify that the RESET lamp starts flashing. Press RESET switch again.

8. Press X10 switch and move the Straightness Interferometer or the Straightness Reflector laterally a few thousandths of an inch. Verify that the display indicates the movement. Press the SMOOTH switch and repeat. (Refer to the 5526A Laser Measurement System Operator's Handbook for information concerning the number of digits to be displayed in each mode.)

9. On the Laser Display, push the TUNE switch to the left and verify that the LASER TUNING meter moves to the left. Hold the TUNE switch to the left until the LASER TUNING meter moves into the red area. Verify that the RESET lamp starts flashing a few seconds after the TUNE switch is released.

10. Push the TUNE switch to the right and hold until the LASER TUNING meter is near the middle of the green area. Release switch and verify that the RESET lamp stops flashing.

11. Push the TUNE switch to the right again and hold until the LASER TUNING meter indicates in the right-hand red area. Verify that the RESET lamp starts flashing a few seconds after the TUNING switch is released.

12. Return LASER TUNING meter to the center of the green area, release TUNING switch, and verify that the RESET lamp stops flashing.

13. Very slowly move the Straightness Interferometer laterally until the returned laser beam misses the entry aperture. Verify that the RESET lamp starts to flash when the BEAM ALIGNMENT meter reaches the red area. This completes the operational test.

PRINCIPLE OF OPERATION

The Straightness Interferometer consists basically of two parts, a prism and a pair of flat mirrors rigidly attached to each other at a precise angle. Figure 3 shows the basic optical schematic of the Straightness Interferometer. Because the composite refractive index of the prism is different for the two planes of polarization that distinguish F1 and F2, the laser beams carrying F1 and F2 exit the prism along different axes with a small included angle (θ). The two beams are reflected back to the prism by two plane mirrors mounted at an angle precisely matched to that of the prism. The F1 and F2 beams are reflected normally to recombine within the prism, and the combined beam is returned coaxially with the transmitted beam to a partial mirror in the Straightness Adapter. Most of the returning signal is reflected down to a 100% mirror that reflects the return beam into the lower aperture of the Laser Head. From there it passes through a demodulating polarizer to a photodetector where it is processed in the normal manner.

Relative lateral displacement between the prism and the mirrors changes the optical path length between the two beams and causes a difference in the accumulated fringe counts. Lateral movement of the mirror assembly with respect to the diverging beams causes a lengthening in the beam from the side to which the mirror assembly moves, and a shortening on the opposite beam. Thus, the mirror axis is the reference straightedge from which lateral movements are measured. For a movement of the prism with respect to the axis of the mirror assembly, there is an optical path length change within the prism that is proportional to the difference in the refractive indicies for each plane of polarization. In either case, for a relative lateral translation of X, the fringe counts accumulated will be equal to 2X Sin $\theta/2$ where θ is the included angle between the diverging beams from the prism. However, if the beam moves with respect to the mirror axis, any path length change in the air space is balanced by a compensating optical path length change within the prism. Thus, the Straightness Interferometer is insensitive to spatial deviations of the laser beam provided that enough signal is returned to keep the 5505A Laser Display BEAM ALIGNMENT meter in the green region.

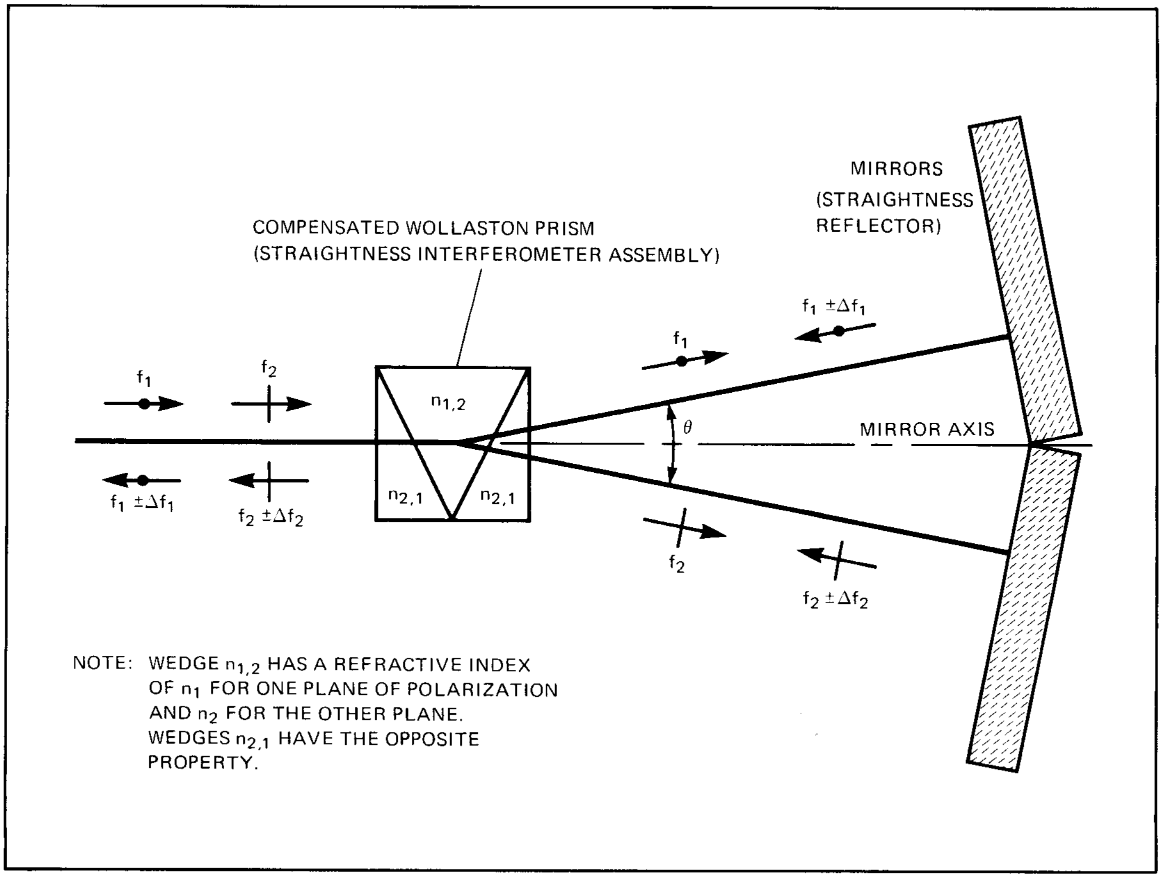
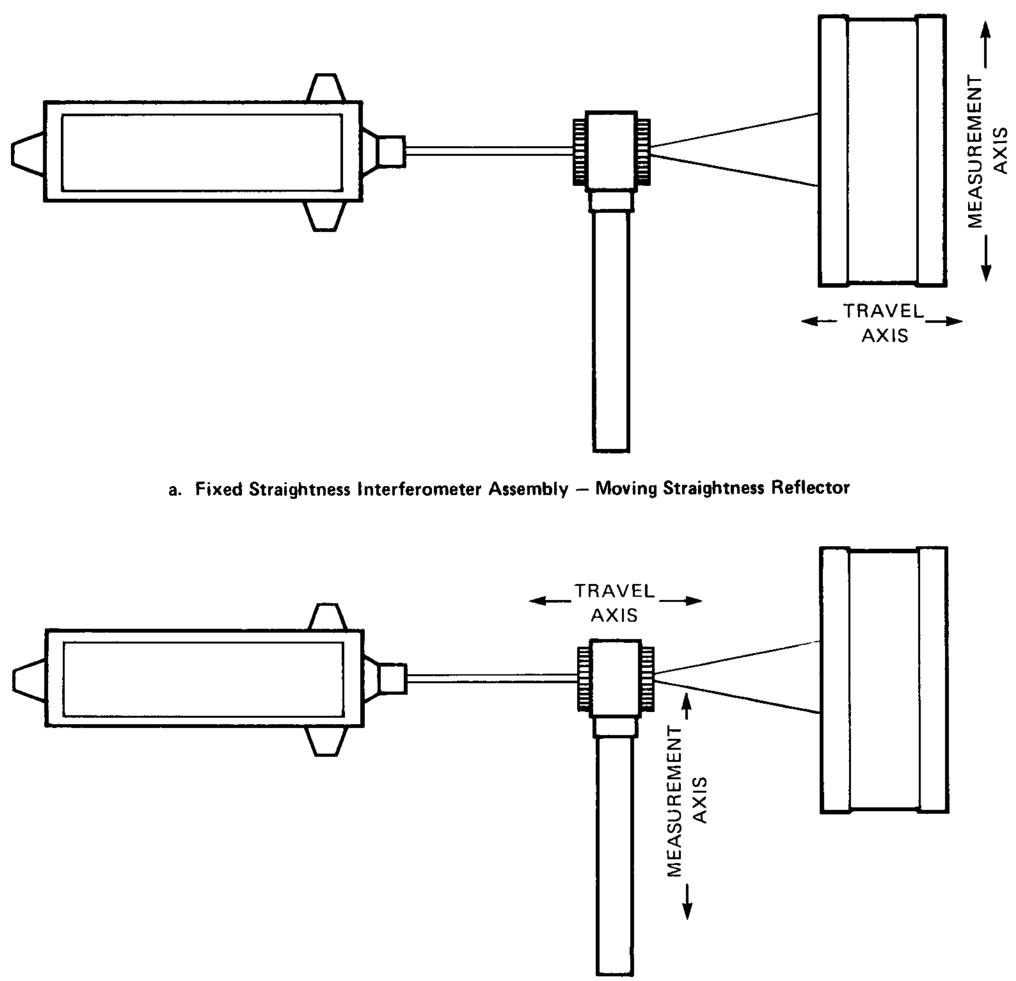


Figure 3. Straightness Interferometer Optical Schematic

To provide a correct readout at the display, the fringe count must be multiplied by the reciprocal of 2 Sin $\theta/2$, which for the value of θ used in the Short-Range Interferometer is 36. The 10579-60004 Resolution Extender electronically provides the multiplication and the Short-Range Interferometer retains the basic resolution of the 5526A Laser Measurement System. The value of θ in the Long-Range Straightness Interferometer is one-tenth of that for the Short-Range Interferometer. When using the Long-Range Interferometer, the resolution of the least significant digit on the display is 0.00001 inch (0.1 micrometer) in the X10 mode and 0.0001 inch (1.0 micrometer) in the NORMAL and SMOOTH modes. Small pitch, yaw, or roll motions of the Straightness Interferometer do not create a path difference and do not affect the measurement accuracy.

MEASURING SETUPS

The measuring setups for straightness, squareness, and parallelism are determined largely by the fixturing facilities available for the major components of the optical system. It is recommended that the 5500C Laser Head be mounted on the 10580A Laser Tripod so that the laser beam can be quickly and accurately aligned with the optical system. Figures 4, 5, and 6 show plan views of basic optical system setups. Refer to page 13 for Optical System Alignment Procedures.



a. Fixed Straightness Interferometer Assembly — Moving Straightness Reflector

b. Fixed Straightness Reflector — Moving Straightness Interferometer Assembly

Figure 4. Straightness Measurements

Squareness Measurement Setups

Squareness measurements can be accomplished with the aid of a pentaprism or an indexing table, and both techniques are illustrated in Figure 5. When using a pentaprism, the laser beam is projected through the pentaprism to the Straightness Reflector as shown in Figure 5a. Once the optical system is aligned, the Straightness Reflector axis must not be disturbed. The Straightness Interferometer Assembly is used to measure straightness of the first axis, and then moved to the second axis.

Figure 5b shows a typical measurement arrangement that uses an indexing table to establish a precise right angle. Essentially, the technique consists of two separate straightness measurement setups with the Straightness Reflector mounted on the indexing table. After the first axis is measured, the indexing table is rotated 90 degrees and the Laser Head and Straightness Interferometer Assembly are moved to the second axis. Alignment on the second axis must be accomplished by adjusting the position of the Laser Head and the Straightness Interferometer Assembly. The Straightness Reflector must not be readjusted.

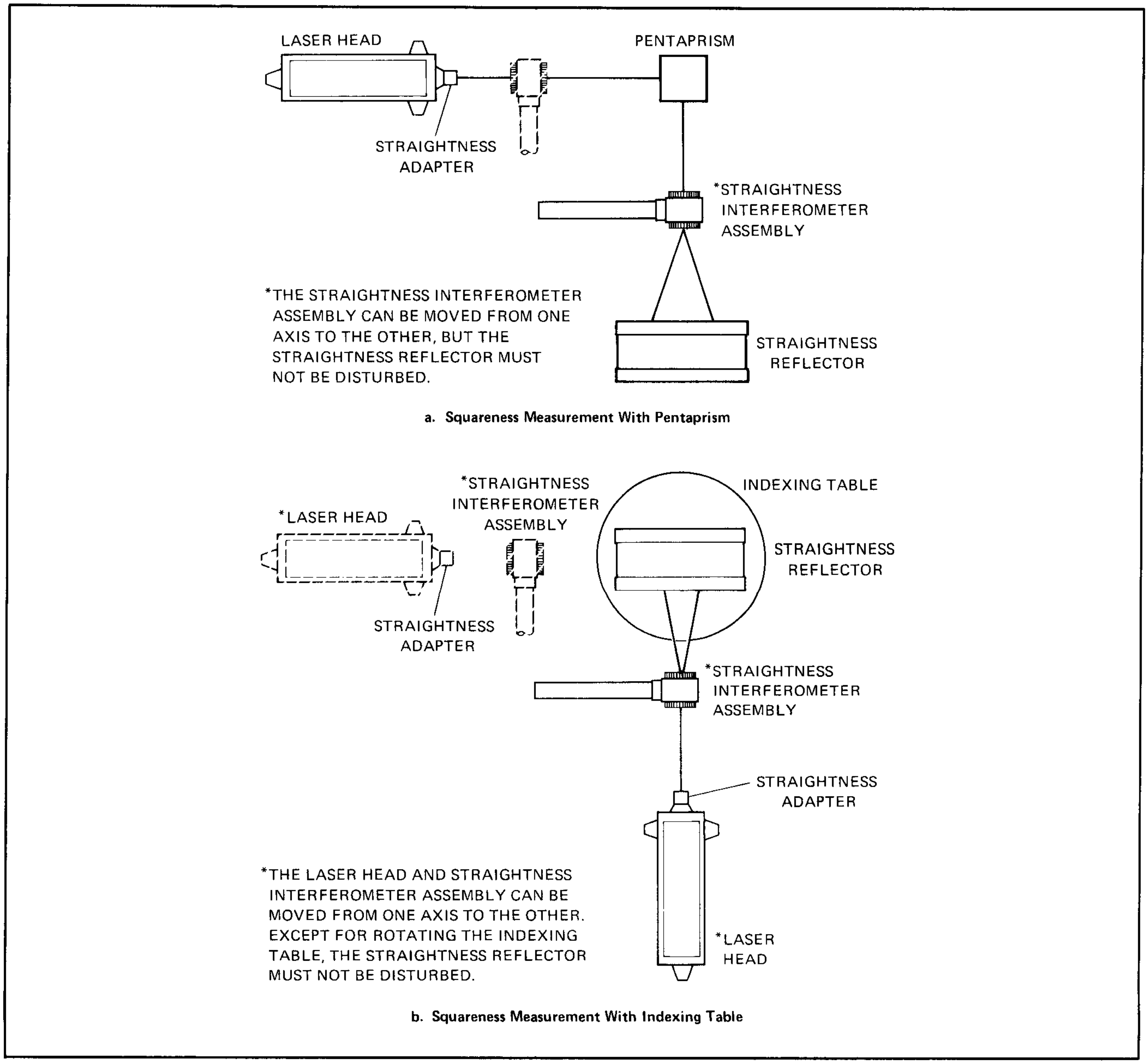
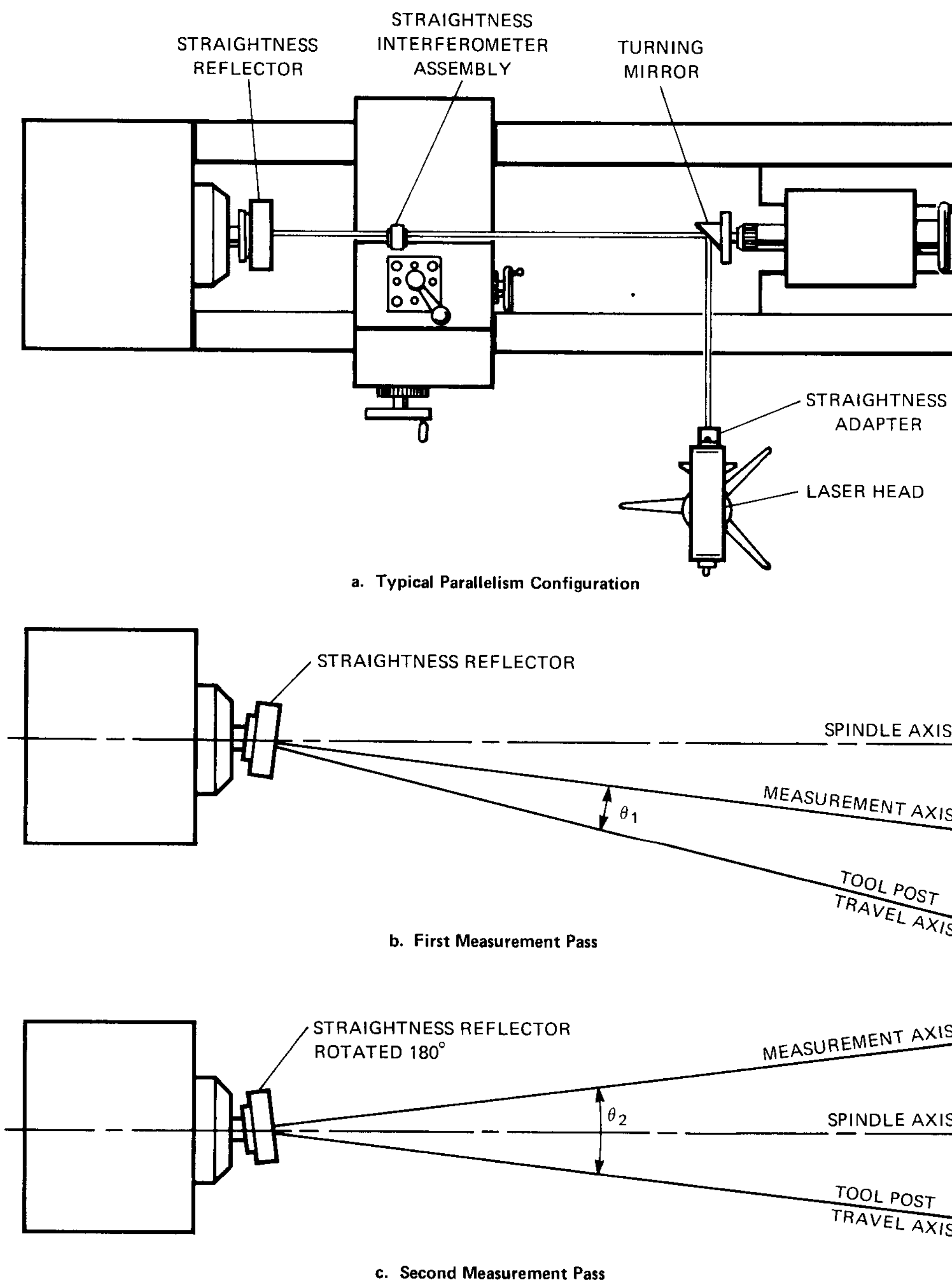


Figure 5. Squareness Measurement

Parallelism Measurement Setup

Figure 6a shows a typical setup that can be used to measure parallelism between the lathe spindle axis and toolpost travel axis. The Straightness Reflector is mounted on the spindle to provide the reference "straightedge" and the Straightness Interferometer Assembly is mounted on the toolpost. The Laser Head is tri-pod mounted perpendicular to the spindle axis with a turning mirror used to reflect the laser beam down the spindle axis. On some machines the laser beam can be projected directly through a hollow tailstock. Removal of a heavy tailstock is not recommended because that would alter the static loading of the lathe bed and introduce additional errors.



Parallelism error equals the angular displacement between the toolpost travel axis and the spindle axis. This is obtained by computing $\theta 1$ and $\theta 2$; then taking 1/2 their algebraic sum.

Figure 6. Parallelism Error

This parallelism measurement technique employs one set of measurements in the horizontal plane, and another set of measurements in the vertical plane. Each set of measurements is performed, using the high resolution straightness interferometer to detect angular displacement between the tool post travel axis and the spindle axis (refer to Figure 6b and 6c). When $\theta 1$ and $\theta 2$ are computed, one-half their algebraic sum comprises the parallelism error in that plane. The horizontal and vertical parallelism error data provides a check of the lathe's ability to function, particularly how closely this machine can turn a perfect cylinder.

After aligning the optical system, verify that the BEAM ALIGNMENT meter on the 5505A Laser Display remains in the green region throughout the expected toolpost travel, (DX) as shown in Figure 7. Two passes must be completed to measure toolpost deviations in the horizontal plane (D_H) as shown in Figure 7a. Two more passes are then performed to measure deviations in the vertical plane (D_V) as shown in Figure 7b. After completing the first pass with the long axis of the Straightness Reflector and the Straightness Interferometer turret in the horizontal plane, the Straightness Reflector (mounted on the spindle) must be rotated 180 degrees, all other Straightness Reflector adjustments remain unchanged. The D_H/D_X readings for both passes are plotted as shown in Figure 8a. Best-fit straight lines are drawn, and the horizontal parallelism error is obtained by computing half the angle included between the D_H/D_X lines of each pass (refer to Figure 8a equations).

Repeat this procedure for vertical plotting by aligning the long axis of the Straightness Reflector (i.e., the spindle) and Straightness Interferometer Turret into the vertical plane as shown in Figure 7b. Complete two passes with the spindle rotated 180 degrees on the second pass. Plot the D_V/D_H curves and compute the vertical parallelism error as shown in Figure 8b.

FIXTURING

When fixturing, remember that the Straightness Interferometers measure relative lateral movement between the Straightness Interferometer Assembly and the Straightness Reflector axis. As far as system operation is concerned, it is not significant whether the interferometer moves, the reflector axis moves, or both move. If the reflector axis moves 0.010 inches while the interferometer moves 0.001 inches, the display will show the algebraic sum of the two distances. Figure 9 shows the physical dimensions of the Straightness Interferometer Components.

CAUTION

The optical components of the Straightness Interferometer Assembly and the Straightness Reflector are precisely adjusted and must not be stressed. Never apply clamping forces directly to the housings. Use mounting plates or bars provided, and apply clamps only to the plates or bars.

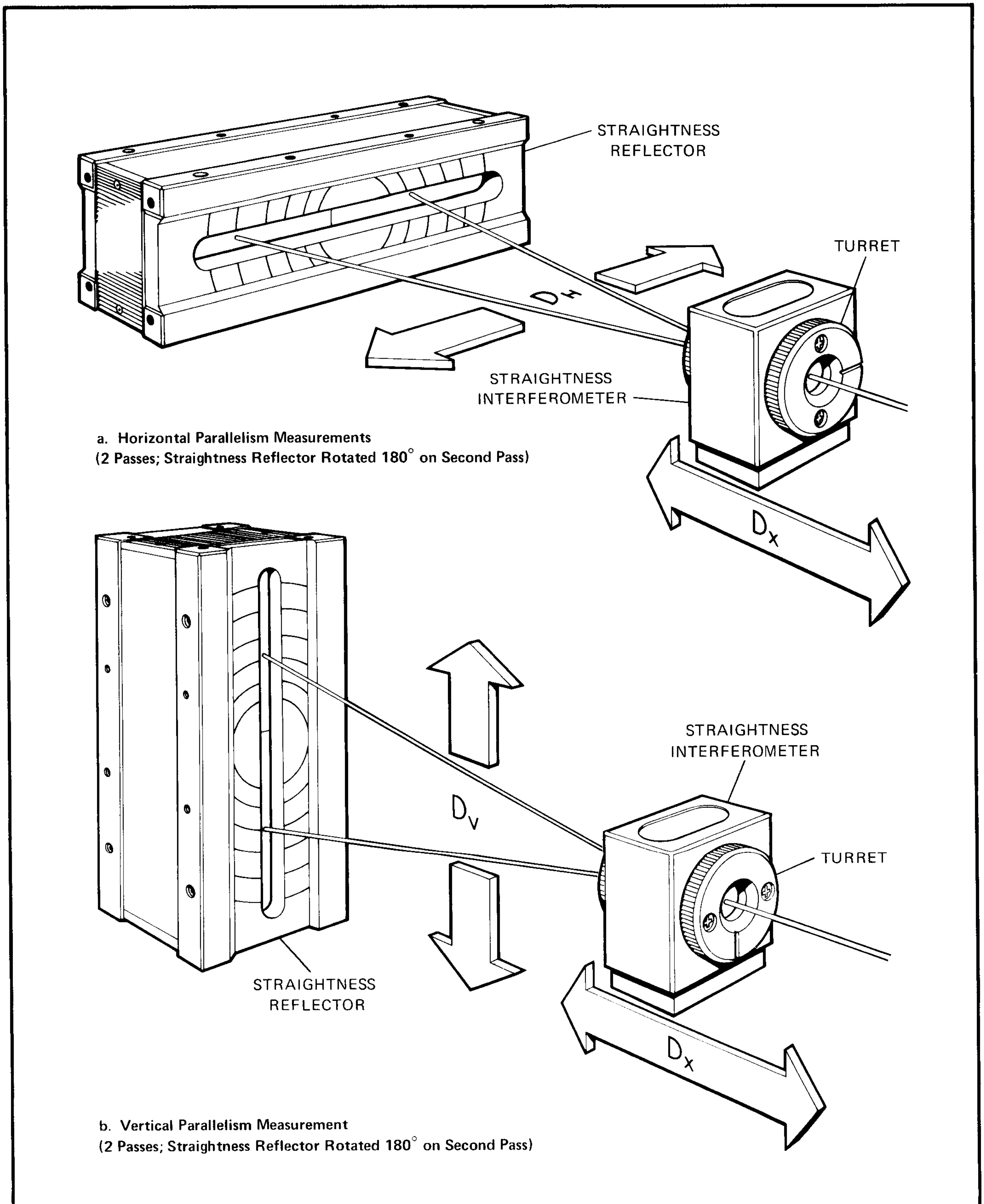
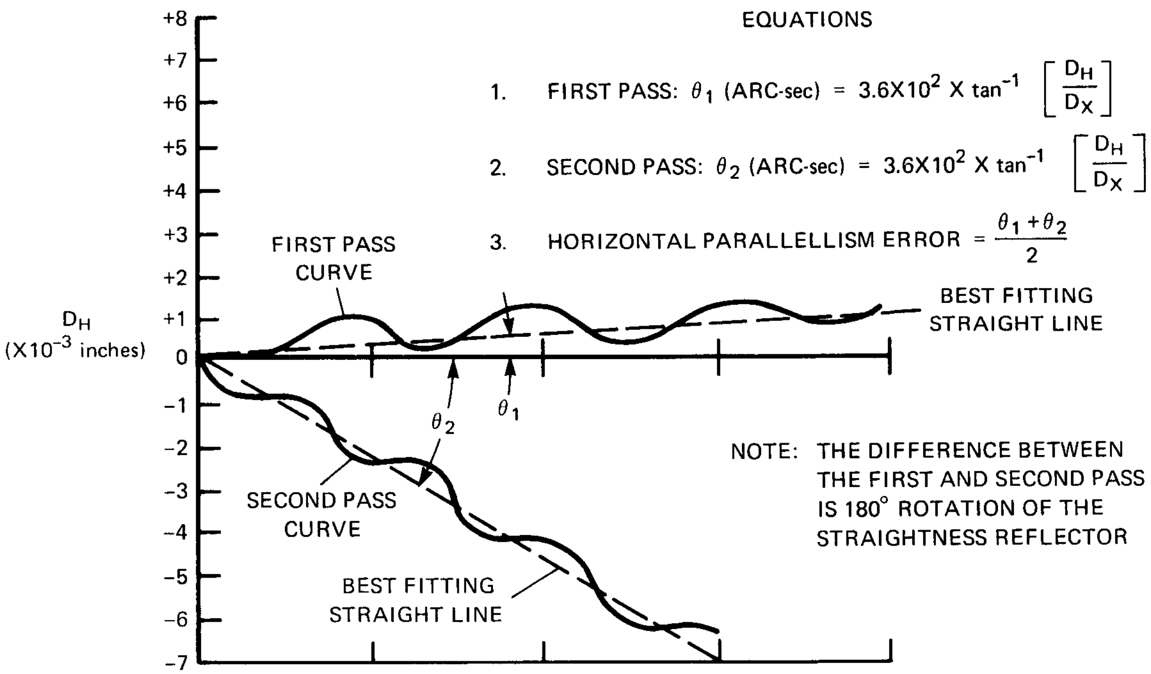
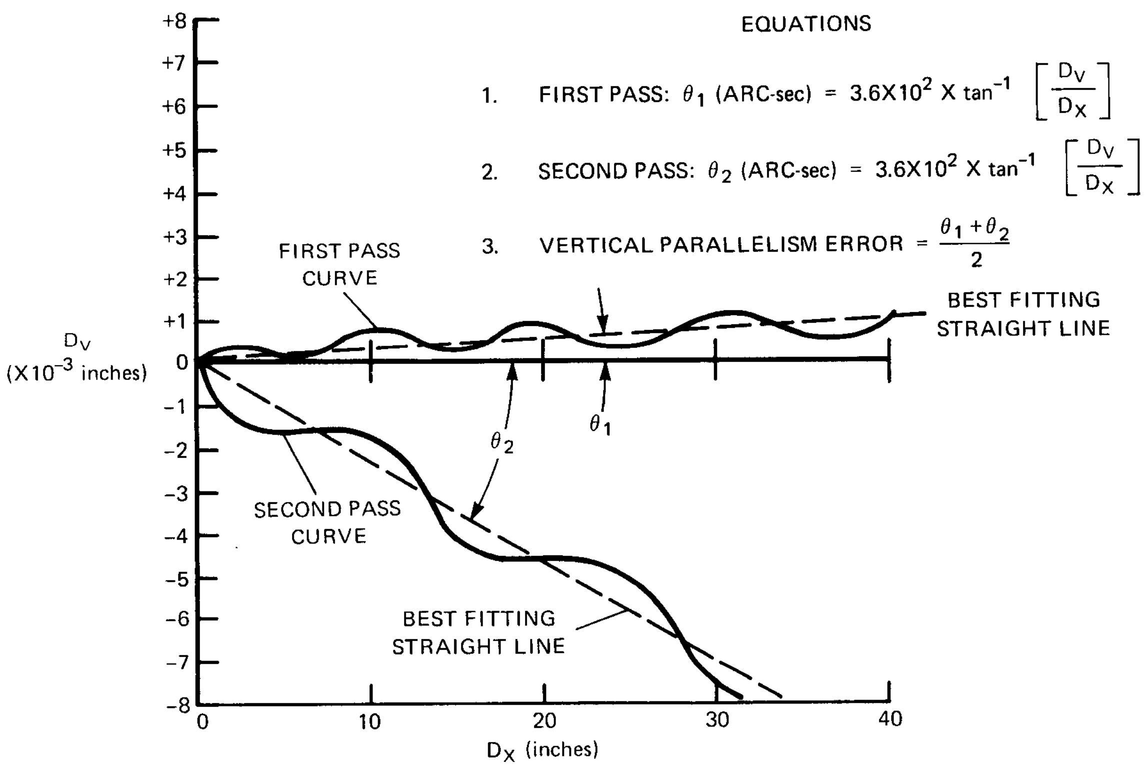


Figure 7. Parallelism Measurements



a. Horizontal Parallelism Error Computation



b. Vertical Parallelism Error Computation

Figure 8. Parallelism Error Computation

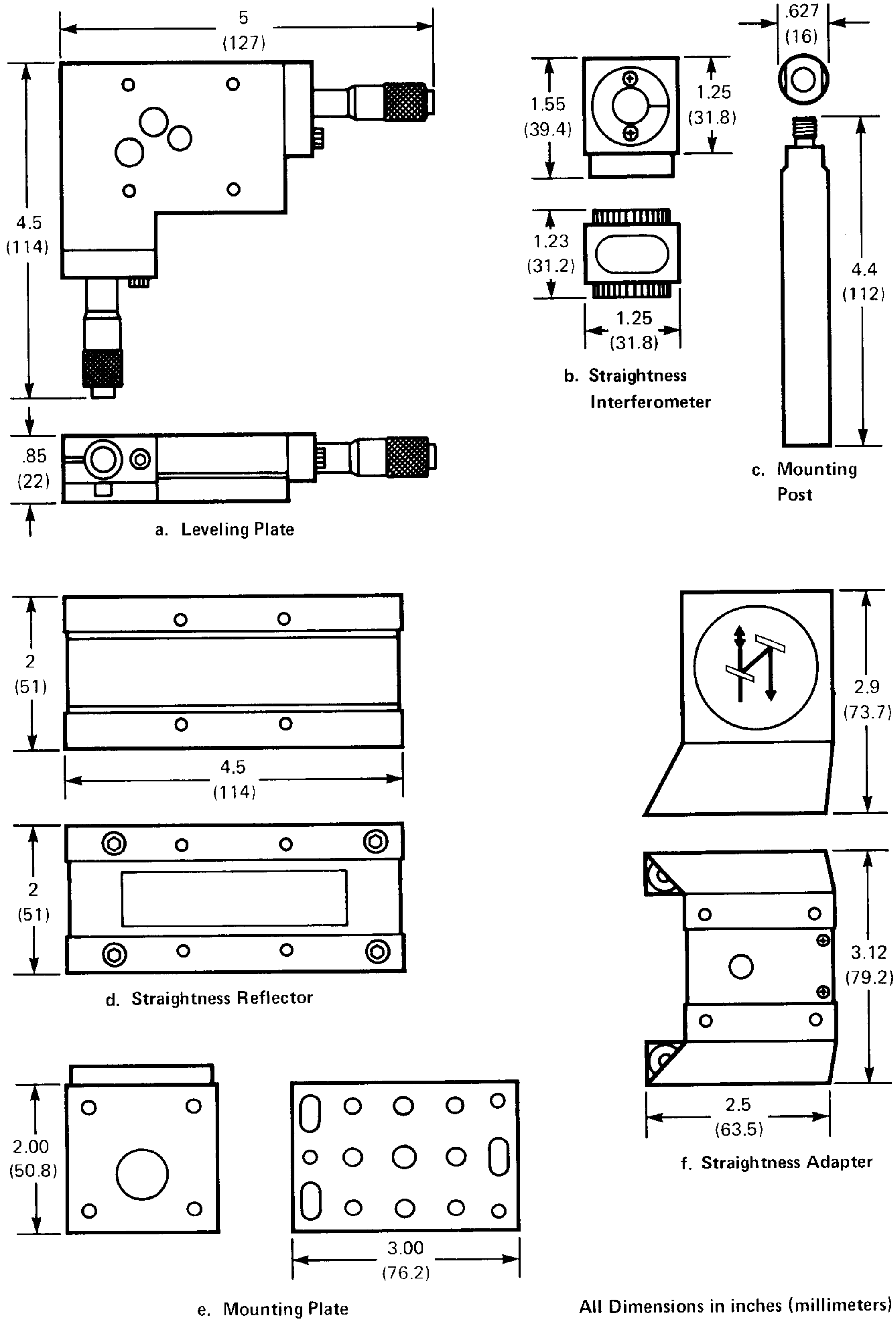


Figure 9. Straightness Interferometer Component Dimensions

OPTICAL SYSTEM ALIGNMENT PROCEDURE

The straightness interferometer uses plane mirror reflectors rather than cube corners. Since plane mirrors do not have the retroreflecting property of cube corners, the straightness interferometer requires more careful alignment. During the alignment procedure, the terms "Near End of Travel" and "Far End of Travel" will be used. Near end of travel is the point at which the straightness reflector and straightness interferometer are closest to one another, regardless of which one travels. Far end of travel is the point at which the straightness reflector and straightness interferometer are farthest from one another, regardless of which one travels. There are three stages to the alignment process, and there are two basic techniques for completing the first stage. The alignment stages are as follows:

- Laser Beam Alignment (parallel to axis of travel)
- Straightness Interferometer Alignment
- Straightness Reflector Alignment

Laser Beam Alignment (Parallel to Axis of Travel)

The laser beam may be aligned by using a visual technique or an autoreflection technique. If the total travel is less than two feet (60 cm), it is recommended that autoreflection be used. If the total travel is greater than two feet (60 cm), either method may be used. As a general rule, autoreflection should be used only with the short-range system; it is very difficult to achieve with the long-range system. A 10557A Turning Mirror is required for the autoreflection technique.

a. Visual Alignment

(1) Attach straightness adapter to front of 5500C using mounting bracket and special front-cover retaining screws.

(2) Attach leveling table to back of straightness reflector mount.

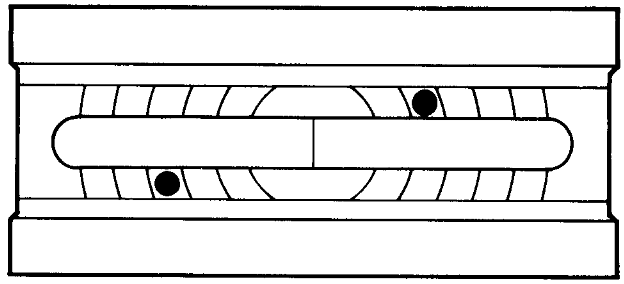
(3) Using shaft provided and vee-block, or mounting plate and magnetic clamp, attach Straightness Reflector assembly to that part of the machine or device under test which would ordinarily support the reference straightedge during a straightness measurement (for machine tools and measuring machine, it is that part of the machine on which the workpiece would be mounted).

(4) Attach Straightness Interferometer to that part of the machine which would ordinarily carry the gage head or indicator during a conventional straightness measurement. The Straightness Interferometer should be oriented so that the lapped adjusting knob faces towards the laser. The milled groove should lie in a plane parallel to the long edge of the Straightness Reflector.

(5) Run the machine slide to the near end of travel. Visually align the Straightness Interferometer so that it is centered with respect to the Straightness Reflector. Do not attempt to adjust the laser head at this time.

(6) Run the machine slide to the far end of travel. Align laser so that the beam passes through the center of the Straightness Interferometer. For the short-range Straightness Interferometer, switch to small aperture.

(7) Adjust the Straightness Interferometer turret so that the two beams on the Straightness Reflector are off-set from the horizontal plane as shown below.



(8) Adjust the Laser Head so that the two beams are equally displaced from the center of the Straightness Reflector.

(9) Run the machine slide back to the near end of travel, and check to ensure that laser beam remains centered in aperture of Straightness Interferometer. If not, repeat steps (5) through (9). This completes visual alignment of the laser.

b. Autoreflection Alignment

(1) Attach straightness adapter to front of 5500C Laser Head. Use mounting bracket and special front-cover retaining screws.

(2) Attach leveling table to back of straightness reflector mount.

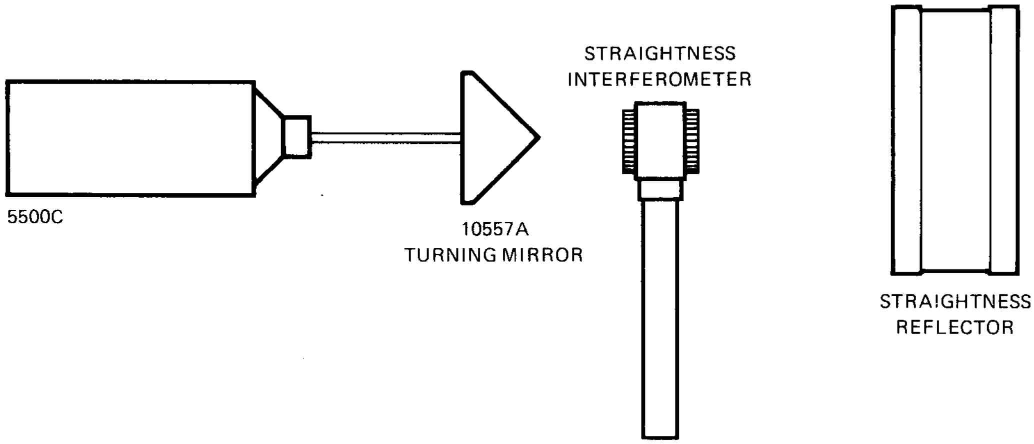
(3) Using shaft provided and vee-block, or mounting plate and magnetic clamp, attach straightness reflector assembly to that part of the machine or device under test which would ordinarily support the reference straightedge during a straightness measurement (for machine tools it is that part of the machine on which the workpiece would be mounted).

(4) Attach striaghtness interferometer to that part of the machine which would ordinarily carry the gage head or indicator during a conventional straightness measurement. The straightness interferometer should be oriented so that the lapped adjusting knob faces towards the laser. The milled groove should lie in a plane parallel to the long edge of the straightness reflector.

(5) Run the machine slide to the near end of travel. Visually align the straightness interferometer so that it is centered with respect to the straightness reflector. do not attempt to adjust the laser at this time.

(6) Align laser so that the beam passes through center of straightness interferometer. For the short-range straightness interferometer, switch to the small aperture on the laser head turret.

(7) Place a 10557A Turning Mirror between the Laser Head and the Straightness Interferometer as shown in the following illustration. Using a dial indicator or gage head, indicate the front ground surface of the Turning Mirror and adjust the Turning Mirror to be perpendicular to the axis of travel whose straightness is to be measured. On many machines, the Turning Mirror front surface may be aligned to a Tee-slot in the table or to the edge of the table. This eliminates the need for indicating the front surface.



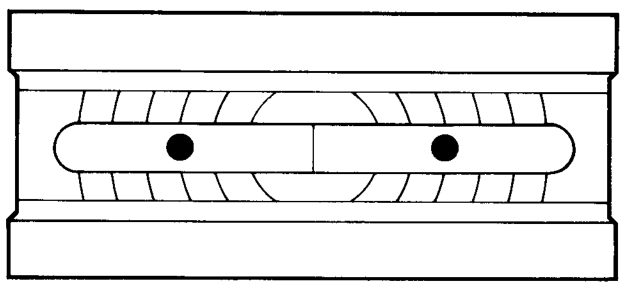
(8) Rotate and level the Laser Head until the laser beam is reflected back into the exit aperture of the Straightness Adapter by the Turning Mirror.

(9) Remove the Turning Mirror and check to ensure that the laser beam passes through the center of the Straightness Interferometer. If not, use the cross slide and height adjustments on the tripod to reposition the laser beam so that it passes through the center of the Straightness Interferometer. DO NOT LEVEL OR ROTATE THE LASER HEAD. This completes alignment of the laser beam by autoreflection.

Straightness Interferometer Alignment

Use the following procedure to align the straightness interferometer.

a. Run machine slide to the far end of travel. Rotate the knurled adjusting ring on the interferometer until the two diverging spots are centered in the straightness reflector aperture as shown in the following illustration.



b. Using the micrometer adjustments, align the Straightness Reflector so the reflected laser beams both pass through the free aperture of the straightness interferometer and the straightness adapter. Switch to the large paerture on the laser head turret.

c. Visually check to assure that the Straightness Interferometer is square to the laser beam. A gage block that can be wrung to the lapped face of the interferometer barrel is provided as a convenience feature if visual alignment is not practical.

d. Set the 10597-60004 Resolution Extender to the STRAIGHTNESS (EXTENDED) mode and observe the BEAM ALIGNMENT meter.

e. Carefully rotate the knurled adjusting ring of the straightness interferometer until the BEAM ALIGNMENT meter indicates well into the green area of the scale. The BEAM ALIGNMENT meter will "peak" very quickly as the rotation adjustment is performed. It is recommended that the knurled ring be rotated very slowly during this adjustment. Normally, the adjustment required will be very slight.

NOTE

Care is advised because false beam alignment could result when the Straightness Interferometer and the Straightness Reflector are aligned in close proximity of each other. This false alignment is characterized by a gradual increase in the meter reading as the interferometer turret is rotated, and by the final position of the interferometer turret notch being offset from the vertical or horizontal plane. To ensure that correct beam alignment is performed, the following characteristics must be observed:
(1) The BEAM ALIGNMENT meter peaks sharply as the interferometer turret is rotated towards the proper position.
(2) In its final position, the notch on the interferometer turret is perfectly aligned in the vertical or horizontal plane.

Straightness Reflector Alignment

Use the following procedure to align the straightness reflector:

a. Run the machine slide to the near end of travel and press RESET switch on the 5505A Laser Display.

b. Run the machine slide to the far end of travel and note laser display. If the display indicated a progressive increase in counts as the machine slide is moved, the mirror axis is not exactly parallel to the machine travel.

c. At the far end of travel, use the micrometer adjustment to align the Straightness Reflector until the display reads zero.

d. Repeat steps a, b, and c until the reflector axis is reasonably parallel to the machine travel. This completes alignment of the Straightness Interferometer system.