
7Y

Agilent 10774A Short Range
Straightness Optics and
Agilent 10775A Long Range
Straightness Optics

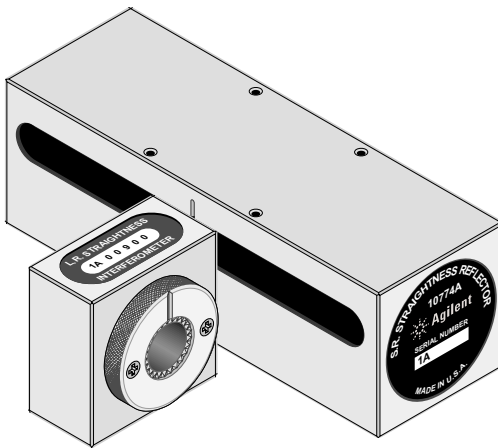
Introduction

Introduction

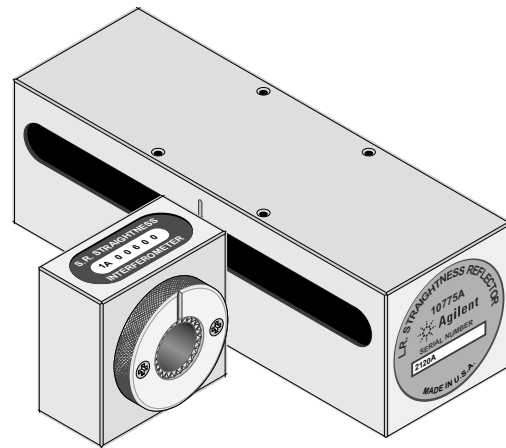
Straightness measures displacement perpendicular to the axis of intended motion of the optics. The straightness measurement optics described in this subchapter are designed for use in a calibrator system such as the Agilent 5529A/55292A. More detailed information about the use of these optics can be found in Agilent calibrator system user's documentation.

Agilent offers two different sets of straightness-measuring optics (see Figure 7Y-1):

- The Agilent 10774A Short Range Straightness Optics will measure straightness over a range of 0.1 meter to 3 meters (4 inches to 120 inches).
- The Agilent 10775A Long Range Straightness Optics will measure straightness over a range of 1 meter to 30 meters (3 feet to 100 feet).



Agilent 10774A
Short Range Straightness Optics



Agilent 10775A
Long Range Straightness Optics

Figure 7Y-1. Straightness optics

The Agilent 10774A is available separately or as part of the Agilent 55283A Straightness Measurement Kit, which also includes the Agilent 10776A Straightness Accessory Kit, the Agilent 10772A Turning Mirror with Mount, and the Agilent 10787A Case.

Squareness and and Parallelism

This subchapter describes only the basic measurements using the Agilent 10774A and Agilent 10775A straightness optics. For descriptions of other optics included in the Agilent 10776A kit, see the *Agilent 5529A/55292A Dynamic Calibrator Measurement Reference Guide*.

Squareness and and Parallelism

A squareness measurement consists of two perpendicular straightness measurements made from the same straightness reflector.

Perpendicularity is achieved using the Agilent 10777A Optical Square. Squareness is calculated by adding or subtracting the slopes from each straightness measurement based on a right angle. For details, see the *Agilent 5529A/55292A Dynamic Calibrator Measurement Reference Guide*.

A parallelism measurement is similar to a squareness measurement, except that it does not use an optical square. A parallelism measurement consists of two straightness measurements made along the same axis from the same straightness reflector. Parallelism is calculated by comparing the slopes of the two straightness measurements. For details, see the *Agilent 5529A/55292A Dynamic Calibrator Measurement Reference Guide*.

Principles of Operation

Principles of Operation

Figure 7Y-2 shows the laser beam path in the straightness optics.

Initially, the two paths from the interferometer to the straightness reflector have the same length.

As the interferometer or reflector is moved along the axis of travel, without lateral motion, both of the beams between them will increase or decrease in length at the same rate. If either the interferometer or the reflector moves perpendicular to the intended axis of motion, the relative lengths of the two beams will change. The change in relative path lengths will be:

$$X = 2D \sin(\theta/2),$$

where D = the distance of offset (out of straightness),

θ = the angle between the two beams leaving the interferometer, and

X = the indicated change in path length

Then:

$$D = X/2 \sin(\theta/2).$$

the angle of the Short Range Interferometer is
1.5916 degrees.

the angle of the Long Range Interferometer is
0.1592 degrees.

Thus, for short range optics, $D = 36X$, and for long range optics,
 $D = 360X$.

Principles of Operation

STRAIGHTNESS OPTICS BEAM PATHS

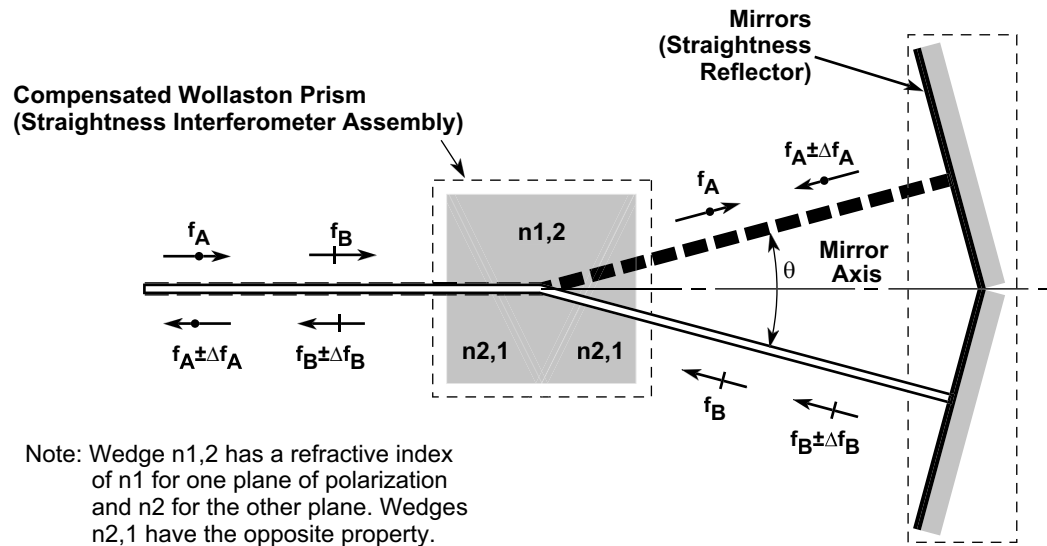


Figure 7Y-2. Straightness optics — beam paths

In practice, the interferometer angles can vary due to manufacturing tolerances. Therefore, the result must be multiplied by the calibration factor, K which is stamped on each interferometer. The final result is $D = 36KX$ for short range optics and $D = 360KX$ for long range optics.

Small pitch, yaw, or roll motions of the interferometer do not create a path difference and therefore do not affect the measurement accuracy.

This is an advantage of using the interferometer as the moving optic. The two return beams from the Straightness Reflector combine in the prism at the same point where the beam from the laser head was split. The combined beam is returned along the same path as the laser head's exit beam.

Installation and Alignment

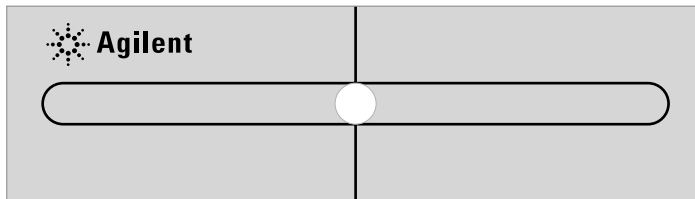
Pre-installation checklist

In addition to reading chapters 2 through 4, and Chapter 15, “Accuracy and Repeatability,” complete the following items before installing a laser positioning system into any application.

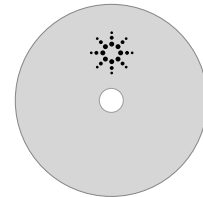
- Complete Beam Path Loss Calculation (see “Calculation of signal loss” in Chapter 3, “System Design Considerations,” of this manual).
- Determine the direction sense for each axis, based on the orientation of the laser head, beam-directing optic, and interferometer. Enter the direction sense for each axis into the measurement system electronics. (See Chapter 5, “Laser Heads,” Chapter 14, “Principles of Operation”, and Chapter 15, “Accuracy and Repeatability,” in this manual.
- Provide for aligning the optics, laser head, and receiver(s) on the machine.

Alignment targets

To help in aligning the straightness interferometers, the alignment targets shown in Figure 7Y-3 are included with each.



Alignment Target
P/N 10774-20021



Alignment Target
P/N 10774-67001

Figure 7Y-3. Alignment Targets for use with straightness interferometers

General considerations

1. Choose the optical configuration carefully for best results. The diagrams in figures 7Y-4 and 7Y-5 indicate which of the possible configurations are acceptable. The diagrams in figures 7Y-6 and 7Y-7 also indicate system performance based on minimizing power returned to the laser head (which can cause instability of the laser output) and maximizing power returned to the receiver.

Chapter 7Y Agilent 10774A Short Range Straightness Optics and
Agilent 10775A Long Range Straightness Optics
Installation and Alignment

SINGLE-AXIS SYSTEM

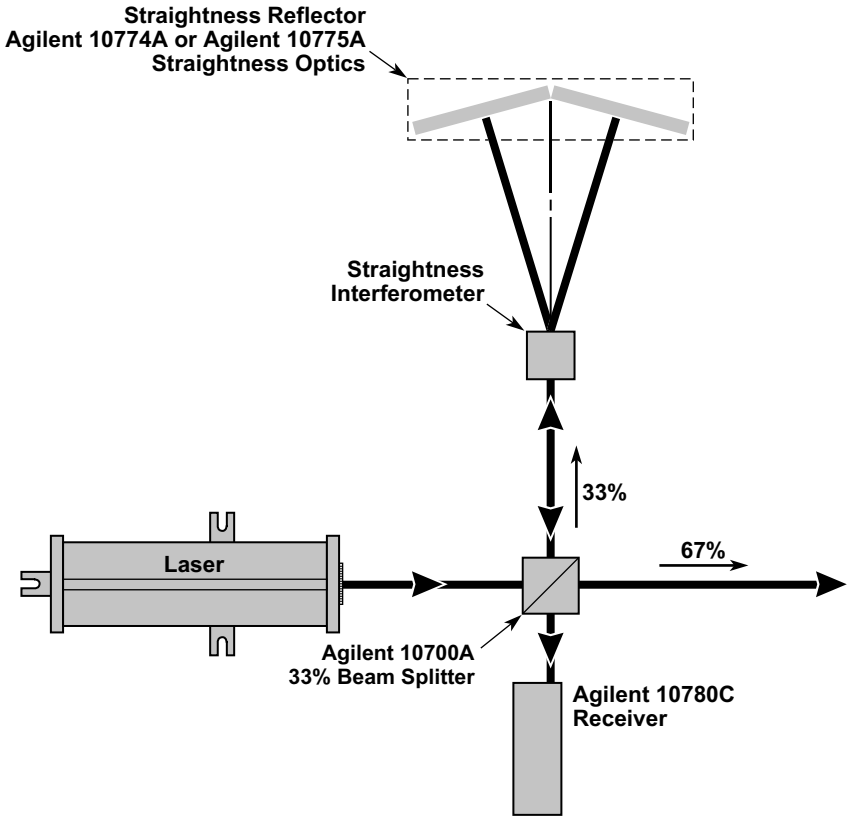


Figure 7Y-4. Single axis system

ONE LINEAR and ONE STRAIGHTNESS AXIS

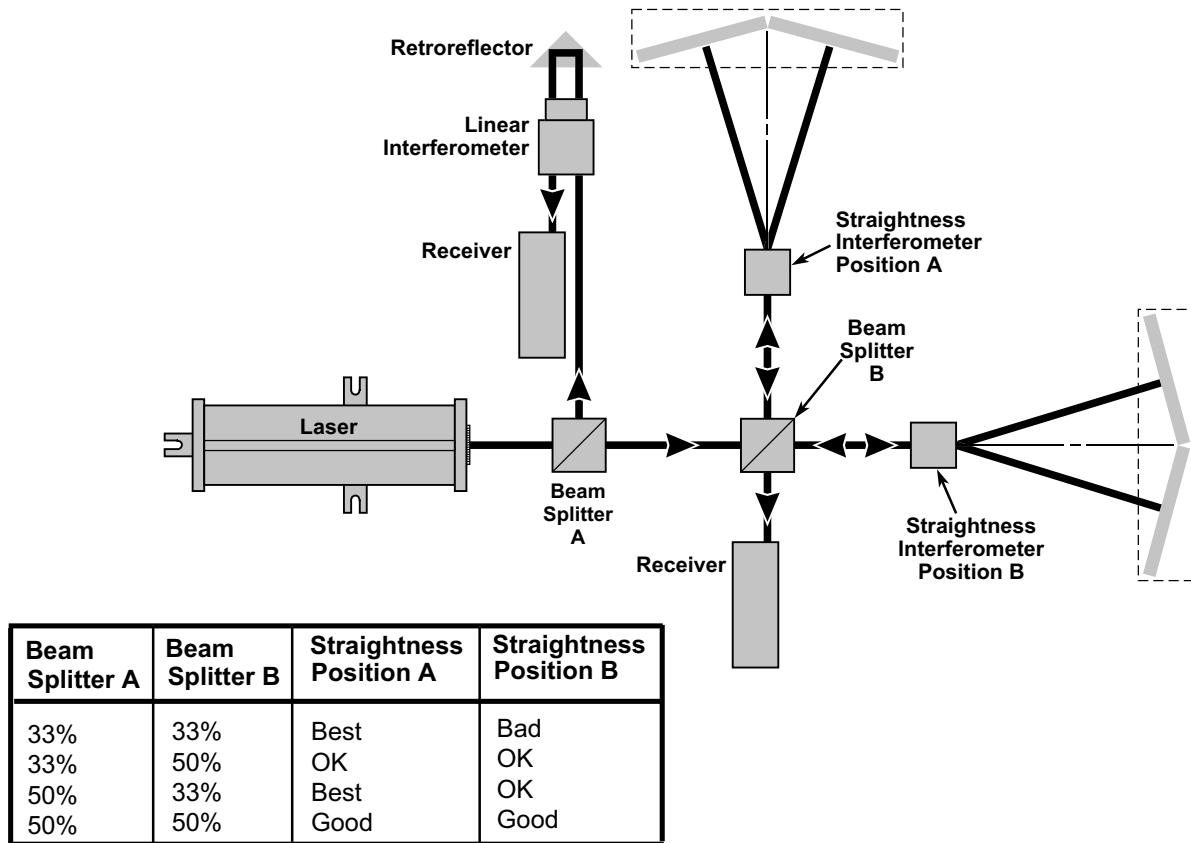


Figure 7Y-5. One linear and one straightness axis

- Supply a rigid mounting surface for both optical components. Fine position adjustments of both components will be necessary. The Straightness Reflector Mount gives full angular adjustment capability for the reflector.
- The Straightness Interferometer must be located between the laser head (or beam-directing optic) and the Straightness Reflector.
- The measurement beams are returned to the receiver. See the previous configuration diagrams.

Installation and Alignment

Principal alignment steps

The principal steps used to align the Straightness optics are listed below, followed by a detailed alignment procedure for a specific configuration.

- 1 The laser head and optics are mounted in the desired locations and the laser beams are visually aligned parallel to the axes of travel.
- 2 Align the laser beam parallel to the axis of travel by using the “Gunsight” or “Autoreflexion” alignment method.

ONE LINEAR and ONE STRAIGHTNESS AXIS

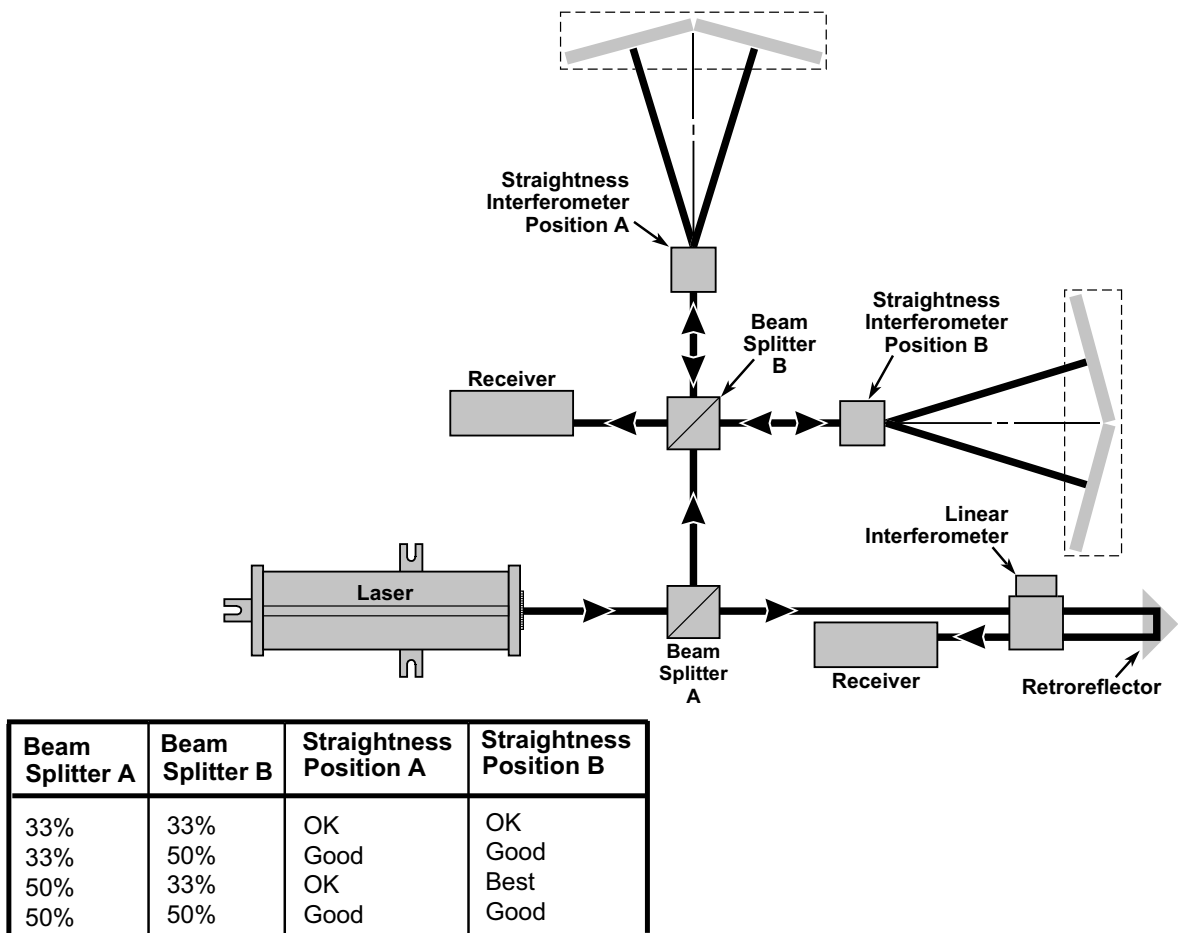


Figure 7Y-6. One linear and one straightness axis

Installation and Alignment

- 3** Align the Straightness Reflector so that its mirror axis (see Figure 7Y-2) is parallel to the laser beam and axis of travel. This mirror axis forms the optical straight-edge (analogous to traditional straight-edge).
- 4** Adjust the interferometer to align its optic to the reflector to obtain a measurement signal at the receiver (green LED is on).
- 5** Fine adjust the interferometer bezel and reflector to obtain maximum measurement signal at the receiver (monitor the voltage at the receiver test point).
- 6** Remove measurement slope. This slope refers to the angle inscribed by the mirror axis and the axis of travel (see Figure 7Y-10).

Alignment procedures

The following procedure describes the step-by-step alignment of an axis of straightness optics. Figure 7Y-4 shows the measurement setup with only the straightness axis shown.

- 1** With all optical components in place, visually align the laser beam parallel to the axis of travel. This may be done by blocking the laser beam with a piece of paper and moving this paper along the axis of travel while watching the beam creative to the axis.
- 2** Align the laser beam even closer to the axis of travel. This may be done by using the “Autoreflexion” or “Gunsight” alignment method. Instructions for these methods are presented after this procedure.

Refer to the basic explanation of this method in Chapter 4, “System Installation and Alignment,” of this manual.

- 3** Remove the interferometer from its mount if not already done. Select the large aperture on the laser head by rotating the front turret. The laser beam should strike the center of the reflector. When properly centered the laser beam will be reflected back as two semicircles. See Figure 7Y-7.
- 4** Adjust the Straightness Reflector angularly (if using the Straightness Reflector Mount, adjust its micrometers) until the reflected semicircular dots are centered about the aperture of the beam splitter. Place a piece of cardboard, with a hole cut in the middle, between the beam splitter and the reflector. This will help locate these dots. The mirror axis of the reflector (the optical straight edge) should now be aligned parallel to the laser beam and the axis of travel.

Installation and Alignment

- 5 Install the Straightness Interferometer so that it is centered about the laser beam. The interferometer should also be perpendicular to the laser beam. This may be done by autoreflecting off the front face with a gage block.
- 6 Rotate the Interferometer's bezel to bring the scribed line parallel to the Straightness Reflector's aperture slot. See Figure 7Y-8. Turn the bezel until the dots overlap on the reflector side of the interferometer. Use a card to locate the return beam and make the appropriate angular adjustments to the reflector to get the beam back through the interferometer and the beam splitter.
- 7 Adjust the receiver position to center the laser beam in its aperture.

REFLECTED SEMICIRCULAR BEAMS

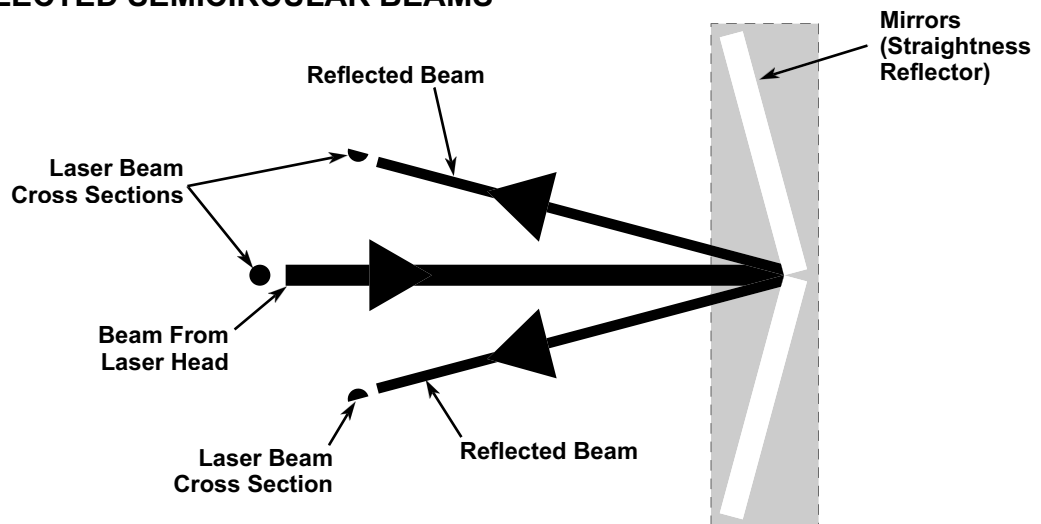


Figure 7Y-7. Reflected semicircular beams

- a. If the receiver LED is not on, carefully rotate the interferometer's bezel until the LED goes on. To maximize the receiver signal, attach a fast responding voltmeter or oscilloscope to the receiver test point and receiver case ground. Only very slight rotation of the bezel is required, typically less than 1 degree.
- b. Fine adjust the Interferometer's bezel and Reflector until the receiver test voltage is maximized. See Chapter 8, "Receivers," in this manual for the adjustment procedures of the Receiver.
- c. Move the optic over its full travel range, making sure that the receiver signal strength is adequate (0.7 to 1.3 Volts) over the entire travel range.

Installation and Alignment

The straightness optics are now aligned. There may be further fine adjustment to be done, but first make several measurement passes and observe the data. If a steady change in the data occurs, rather than either a random scattering of numbers or a constant number, this indicates misalignment between the axis of travel and the reflector's mirror axis. See Figure 7Y-10 for an illustration of this error. This error is called "slope", and must be removed to obtain proper straightness information.

Autoreflexion method

- 1** Remove the Straightness Interferometer from its mount surface.
- 2** Place a referenced mirror or gage block between the beam splitter and reflector so that the laser beam strikes its reflective surface.
- 3** Align the referenced mirror until its reflective surface is perpendicular to the axis of travel.
- 4** Select the small aperture on the laser head by rotating the front turret.
- 5** Adjust the laser beam angularly until the beam reflects back on itself from the referenced mirror and is centered on the small aperture of the laser head. Make sure that the laser beam is centered over the intended measurement axis.
- 6** Lock down the laser head and beam splitter securely. Make sure not to disturb the alignment. Remove the referenced mirror.
- 7** Orient the Straightness Reflector horizontally or vertically to match the type of measurement to be made (horizontal or vertical straightness).
- 8** Center the reflector about the laser beam. The laser beam should strike centered between the two mirrors in the reflector. The laser beams should now be aligned parallel to the axis of travel.

This ends the "Autoreflexion" alignment method.

Installation and Alignment

Gunsight method

- 1** Position the optics for their near-end of travel, that is when the interferometer and reflector are nearest each other. For short range measurements this should be about 100 mm (4 inches). For long range measurements this should be about 1 meter (3 feet).
- 2** Orient the Straightness Reflector horizontally or vertically to match the type of measurement to be made (horizontal or vertical straightness).
- 3** Select the small aperture on the laser head by rotating the front turret.
- 4** Attach the round target (supplied with the straightness optics) to the entrance face of the interferometer. Make sure that the target is centered over the interferometer bezel.
- 5** Adjust the interferometer (or laser beam) so the laser beam goes through the target's hole. The interferometer should be mounted perpendicular to the laser beam. This may be done by autoreflecting off the front face with a gage block.
- 6** Rotate the interferometer's bezel until the bezel's scribe line (see Figure 7Y-8) is oriented perpendicular to the aperture slot on the Straightness reflector. Two beams should now exit the interferometer in a plane perpendicular to the aperture slot on the reflector.

AGILENT 10774A OR HP 10775A STRAIGHTNESS INTERFEROMETER

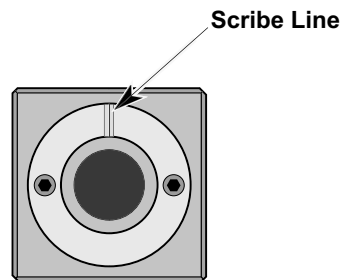


Figure 7Y-8. Agilent 10774A or Agilent 10775A Interferometer scribe line

- 7** Position the reflector so that the two dots are located over the scribed center-line of the reflector housing and the face is square relative to the incoming beam. See Figure 7Y-8.
- 8** Move the optics to their far-end of travel.

Installation and Alignment

- 9 Realign the laser beam, in this case by using the 33% beam splitter, so that the two dots are located over the scribed center-line of the reflector housing. See Figure 7Y-9.

Since the dots will move apart as the optics move, you may have to hold a card on each side of the reflector's slot to follow their movement. The beam splitter may need to be translated to re-center the laser beam in the interferometer target. The laser beam should now be aligned parallel to the axis of travel.

POSITIONING OF REFLECTOR

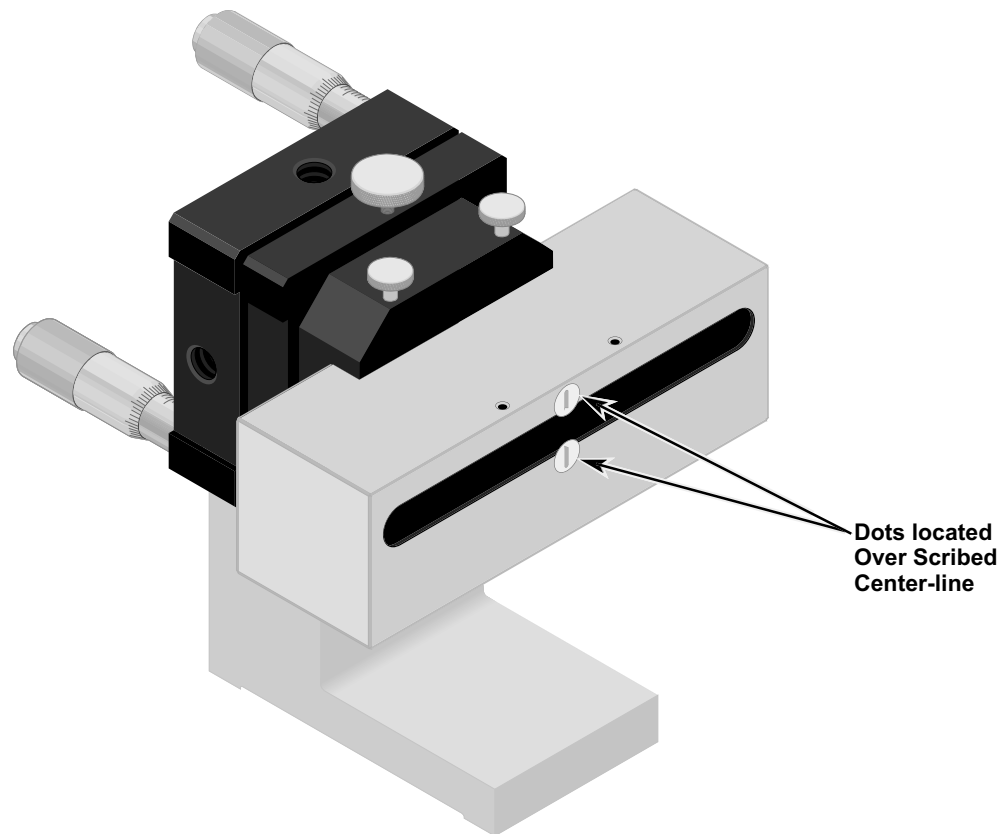


Figure 7Y-9. Initial Positioning of Reflector

This ends the “Gunsight method” alignment method.

Installation and Alignment

Slope removal

The slope should be removed as much as possible by readjusting the Straightness Reflector's mirror axis. Slope removal is typically required only for the short range optics because long range alignment is normally more accurate. Slope removal can be done by the following procedure.

- 1 Reset the measurement (reset the counter to zero) with the optics at the near-end of travel.
- 2 Move the optics to the far-end of travel and note the last data point (see Figure 7Y-10).

SLOPE ERROR

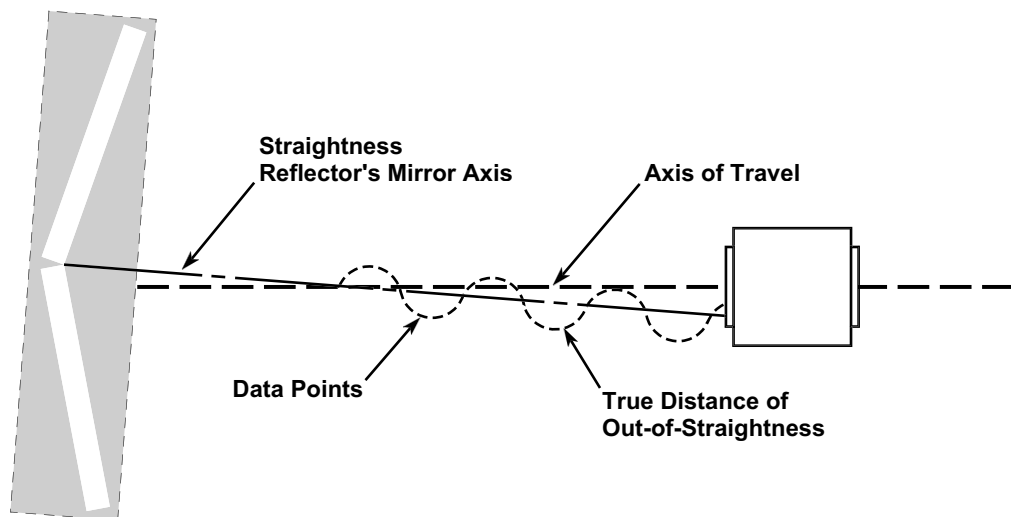


Figure 7Y-10. Slope Error

- 3 Adjust the reflector (if using the straightness mount, adjust the micrometer) in the plane of the reflector's aperture slot to cause the straightness measurement to change to the following calculated value.:

$$x = (r/s)d$$

where x = the new value

r = distance between optics at near-end of travel,

s = distance of moving optic at far-end of travel,
and

d = old value read.

See Figure 7Y-11 for a representation of this.

MANUAL SLOPE REDUCTION

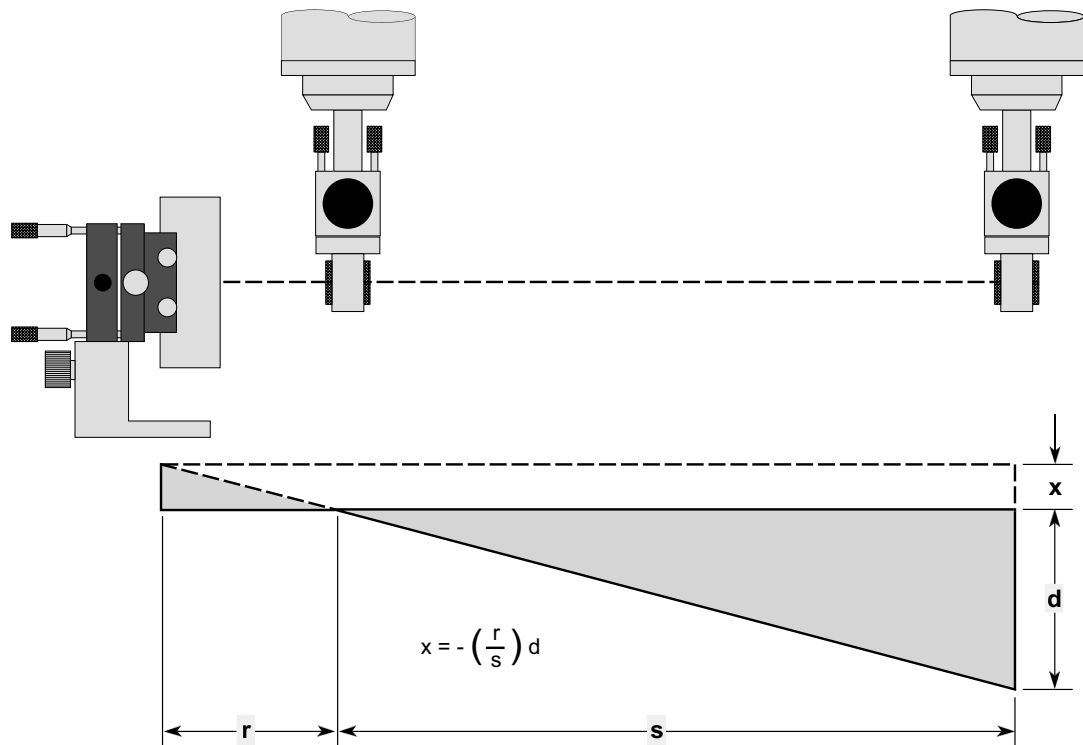


Figure 7Y-11. Manual Slope Reduction

- 4** Reset the measurement again, and return the optics to the near-end of travel.
- 5** If the signal strength gets too low, adjust the laser beam to achieve peak signal strength.
- 6** Repeat steps a through e as often as necessary to make the straightness measurement at both ends of travel to be near “zero”.

The alignment procedure for the straightness optics is now complete.

Operation

Operation

When taking straightness data, there will still be some residual slope that has not been removed. During data reduction the best-fit straight line should be determined and the straightness errors recalculated based on that line.

Accuracy considerations

There are several sources of error under the control of the operator.

- The calibration factor on the interferometer must be used to obtain the correct value. Multiply the measured value by the interferometer calibration factor number to get the correct straightness.
- The optical reference accuracy term can be eliminated by rotating the mirror 180° and making another measurement.
- The slope must be removed manually or in software.
- Environmental conditions (such as temperature changes of the machine or optics, vibration, and air turbulence) can cause errors.

Errors due to thermal expansion can be minimized by allowing the machine and optics to reach thermal equilibrium before making a measurement.

The effects of vibration can be reduced by good fixturing, averaging successive runs, reducing the slew rate, and more accurate manual slope removal.

Air turbulence effects can be minimized by using baffles, while thermal gradient effects can be minimized by mixing the air with fans.

Specifications

Specifications describe the device's warranted performance. Supplemental characteristics (indicated by TYPICAL or NOMINAL) are intended to provide nonwarranted performance information useful in applying the device.

Specifications

**Agilent 10774A Short Range Straightness Optics and
Agilent 10775A Long Range Straightness Optics
Specifications**

ACCURACY:

Overall accuracy =
Optical Reference Accuracy + Measurement Accuracy
(This is analogous to the traditional straight-edge and indicator method of measuring straightness, where Optical Reference Accuracy corresponds to the straight-edge accuracy, and Measurement Accuracy corresponds to the indicator accuracy.)

OPTICAL REFERENCE ACCURACY:

This can be eliminated by using straight-edge (mirror) reversal techniques.

Short Range Optics:

Metric Units Mode: $\pm 0.15 M^2$ micron
English Units Mode: $\pm 0.5 F^2$ microinch
where M = distance of travel of the moving optic in meters, and
F = distance of travel of the moving optic in feet.

Long Range Optics:

Metric Units Mode: $\pm 0.015 M^2$ micron
English Units Mode: $\pm 0.5 F^2$ microinch
where M = distance of travel of the moving optic in meters, and
F = distance of travel of the moving optic in feet.

MEASUREMENT ACCURACY:

Short Range Optics

| Temperature Range | Displayed Value | |
|-------------------|---|---|
| | 0-10 μm (0-400 μin) | 10-1500 μm (400-60000 μin) |
| 15-26 °C | $\pm 3.5\%$ | $\pm 1 \pm 0.25 \mu\text{m}$ (10 μin) |
| 0-40 °C | $\pm 6\%$ | $\pm 1\% \pm 0.5 \mu\text{m}$ (20 μin) |

Long Range Optics

| Temperature Range | Displayed Value | |
|-------------------|---|---|
| | 0-100 μm (0-4000 μin) | 100-1500 μm (400-60000 μin) |
| 15-26 °C | $\pm 3.5\%$ | $\pm 1 \pm 0.25 \mu\text{m}$ (10 μin) |
| 0-40 °C | $\pm 6\%$ | $\pm 1\% \pm 0.5 \mu\text{m}$ (20 μin) |

STRAIGHTNESS MEASUREMENT RESOLUTION:

| | Basic | |
|--------------------|----------------------------------|----------------------------------|
| | Short Range Optics: | .35 micron (14.0 microinches) |
| Long Range Optics: | 3.6 microns (140 microinches) | 0.01 micron (4.0 microinch) |

STRAIGHTNESS MEASUREMENT RANGE: ± 1.5 mm 0.060 in.

AXIAL SEPARATION:

(Typical, with proper alignment, 15-25° C, distance between the interferometer and reflector)

Short Range Optics: 0.1-3 m (4-120 in)

Long Range Optics: 1-30 m (3-100 feet)

Dimensions: see Figure 7Y-12 on next page

Weight:

Straightness Interferometer: 164 grams (5.8 ounces)

Straightness Reflector: 800 grams (28.2 ounces)

Materials Used:

Housing: Stainless Steel (416)

Apertures: Plastic (Nylon)

Optics: Optical Grade Glass

Adhesives: Low Volatility (Vacuum Grade)

Optical Efficiency: 90% (Worst Case)

Specifications

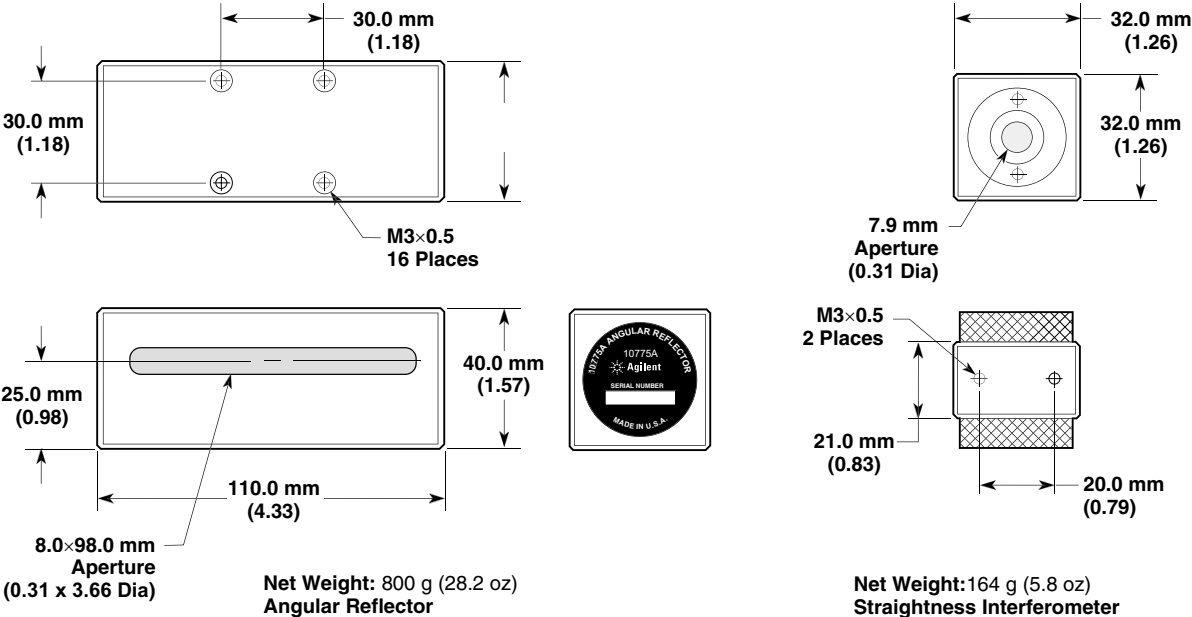


Figure 7Y-12. Agilent 10774A Short Range Straightness optics and Agilent 10775A Long Range Straightness optics

Chapter 7Y Agilent 10774A Short Range Straightness Optics and
Agilent 10775A Long Range Straightness Optics
Specifications