ZMI
Straightness Interferometer
Accessory Manual
OMP-0225G

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MANUAL REVISION INFORMATION

The document (OMP) number and latest publication date for this manual appear on the title page. Any revision letter following the document number indicates that the manual has been revised. Revision letters also appear at the bottom of each revised page.

Revision	*Publication Date*
First release	May 1991
B	January 1992
C	March 1992
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E	July 1993
F	September 1999
G	December 2001

MANUAL NOTATIONS

Warning! Denotes a hazard that could cause injury to personnel, and can also cause damage to the equipment.

Note: Provides helpful information.

ZYGO STATEMENT OF WARRANTY AND PRODUCT SUPPORT

Zygo Corporation provides this warranty to protect its customers from defects in product workmanship or product materials. This warranty covers all products manufactured by Zygo Corporation. Zygo warrants that the equipment purchased will be free from any defects in material and/or workmanship under normal operating conditions for a period of one year from the date of shipment.

In addition, being committed to providing our customers with superior service, Zygo will support all standard products for a period of five years after the sale of the last newly-manufactured unit. Beyond this five-year period, we will continue to support these products on a "best-effort" basis.

WARRANTY SERVICE

Zygo's responsibility under this warranty shall be limited to the repair or replacement (at Zygo's option) of defective equipment at no cost to the buyer, except for transportation, cleaning, and recalibration charges.

Zygo will perform warranty service by: (1) sending replacement parts with appropriate installation instructions to the buyer, the buyer returning his defective part to Zygo or; (2) repairing the product at a Zygo repair facility after it has been returned freight prepaid, or; (3) at the buyer's request, dispatching a service representative to the buyer's facility. The buyer shall pay Zygo's travel and living expenses as well as travel time.

Defective products or parts will be repaired or replaced with new or like-new parts. These replacement parts will be warranted for a period of 90 days after they are shipped, or for the remainder of the original warranty period, whichever is longer. Warranty service will be performed only if the buyer notifies Zygo within 14 days of discovering any defects. Equipment or parts that are to be returned to Zygo must be issued a Return Authorization number. This number can be obtained by contacting the Zygo Service Department. Should Zygo's subsequent inspection reveal that the parts were not defective, all expenses incurred by Zygo shall be charged back to the buyer. Defective equipment that is replaced shall become the property of Zygo.

Warranty period begins when the product is shipped from Zygo. Replacement parts, service workmanship, used equipment, and refurbished equipment are warranted for a period of 90 days.

RETURNS

Unused and undamaged products, in their original shipping containers, may be returned for credit within 30 days of receipt. All such products will be subject to a restocking fee equal to 20 percent of the purchase price. Custom products are not returnable.

EXCLUSIONS

The above warranty and product support statement applies only to equipment that is an integral part of a Zygo manufactured product. It does not apply to peripheral equipment manufactured by others, such as: computers, printers, vibration isolation tables, etc. In such cases, the warranty and the support that the original manufacturer supplies will apply.

In addition, warranty service does not include or apply to any product or part which, in Zygo's judgment:

a. Has been repaired by others, improperly installed, altered, modified, or damaged in any way.
b. Malfunctions because the customer has failed to perform maintenance, calibration checks or good operating procedures.
c. Is expendable or consumable (such as panel lights, fuses, batteries, windows, and filters) if such items were operable at the time of initial use.
d. Requires replacement because of decomposition due to chemical action.
e. Fails because of poor facility, operating conditions, or utilities.

Other than expressly described above, Zygo makes no express or implied warranties, including any regarding merchantability or fitness for a particular purpose relating to the use or performance of the equipment. Zygo will not be liable for personal injury or property damage (unless caused solely by its own negligence), loss of profit or other incidental or consequential damages arising out of the use or inability to use the equipment. Nor does this warranty apply to any equipment which has been subject to misuse, neglect or accident; or repaired or altered by other than service representatives qualified by Zygo.

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STRAIGHTNESS INTERFEROMETER

Introduction

The Zygo Straightness Interferometer* is a high performance double pass interferometer, designed to be used in conjunction with the Zygo laser measurement system. It is used to measure straightness of travel, or the deviation of an object from a straight line of travel. The Straightness Interferometer consists of three major components: a Model 7020 Straightness Interferometer Module, a Model 7020A Straightness Prism, and a Model 7020D Straightness Mirror.

There are two models of the Straightness Interferometer. Model 7020-01 is the complete Straightness Interferometer; Model 7020-02 is a Straightness Interferometer Kit, which contains the necessary components to convert a Zygo Model 7015 Differential Plane Mirror Interferometer to a Straightness Interferometer. The complete interferometer is shown in Figure 1.

The Straightness Prism is mounted on a movable object, such as a translation stage, of which the straightness of travel is measured. The Straightness Interferometer Module and the Straightness Mirror are fixed at opposite ends of the travel axis. The Straightness Interferometer measures the lateral motion of the Prism at right angles to the laser beam.

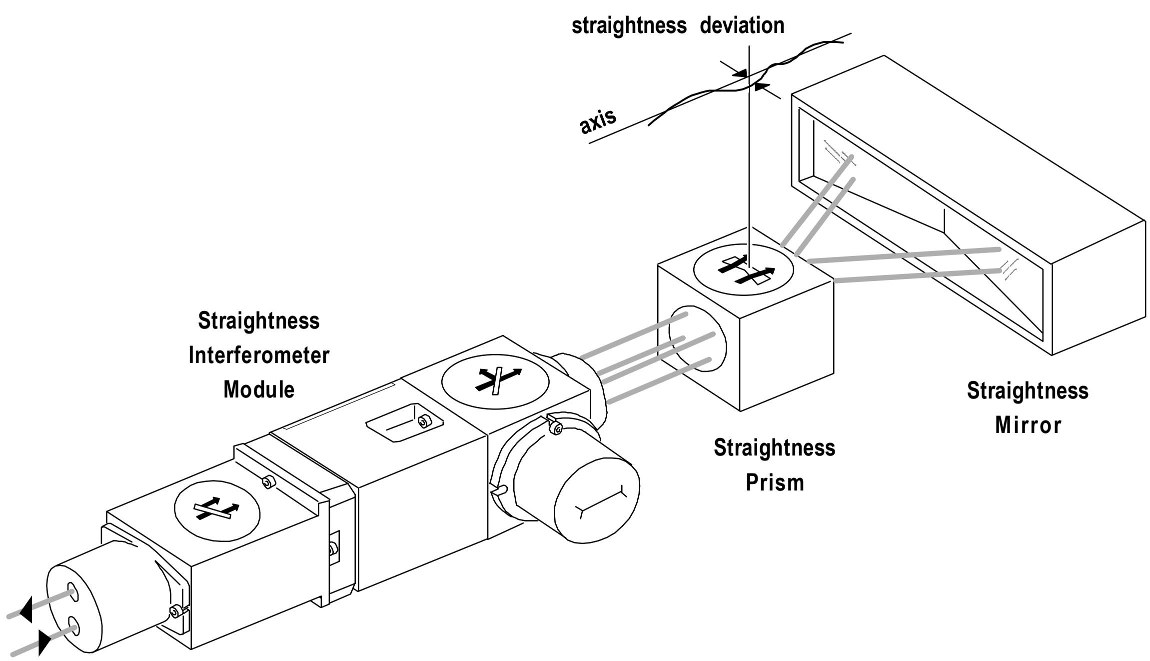


Figure 1 Straightness Interferometer

*U.S. Patent Number 4,787,747. Foreign Patents Pending.

What This Manual Covers

This manual explains the installation and use of the Straightness Interferometer. The following topics are covered:

- Description
  - Theory of Operation
- Installation
  - Assembly
  - Mounting
- Optical Alignment
- Accuracy and Installation Considerations
- Maintenance
- Contacting Zygo Service Department
- Specifications

Description

The Straightness Interferometer is used to measure the deviation of a moving Straightness Prism. The Straightness Interferometer consists of three major components: a Model 7020 Straightness Interferometer Module, a Model 7020A Straightness Prism, and a Model 7020D Straightness Mirror. These three components are described in the paragraphs that follow. Additional information can be found in the specifications located at the end of this manual.

The Straightness Interferometer Module is comprised of a Beam Translator, a Polarization Shear Plate, a Half Waveplate, a Beam Switch Prism, a Polarization Beamsplitter, a Split Retroreflector, and a Quarter Waveplate. These components direct the incoming laser beam so four beams are output to the Prism. They also direct the returning beams from the Straightness Mirror to a receiver or Fiber Optic Pickup. The functions of these components are listed below.

Component	*Model*	*Function*
Polarization Beamsplitter	7008	Reflects or transmits a beam depending upon its polarization.
Polarization Shear Plate	7012	Splits the beam into two parallel beams of different polarizations, which are equally displaced from the incoming beam.
Beam Translator	7016	Converts 12.7 millimeter beam spacing to 9 millimeter spacing.
Split Retroreflector	7020B	Reflects the beam back parallel to the incident beam.
Beam Switch Prism	7020C	Switches the lateral position of two beams output from the Polarization Beamsplitter.
Half Waveplate	7021	Rotates the beam polarization 90 degrees with *one* pass.
Quarter Waveplate	7022	Rotates the beam polarization 90 degrees with *two* passes.

The Straightness Prism is mounted to a translation stage whose travel is being monitored. The Prism bends the beams as they are directed to and from the Straightness Mirror. As the Prism shifts perpendicular to the axis defined by the beams output from the Straightness Module, a deviation is indicated.

The Straightness Mirror reflects the beams output from the Straightness Prism back to the Prism. The Mirror is fixed in position.

> **Note:** The Straightness Prism and Mirror are a matched set; a mirror from one Straightness Interferometer should not be used with another Prism from a different set. If it is necessary to replace a Prism or Mirror, contact Zygo.

The Straightness Interferometer measures the deviation of a nodal axis on the Straightness Prism. The nodal axis is a vertical axis through the center of the Prism. When this nodal axis moves laterally, the interferometer indicates a straightness deviation.

The measurement range of the Straightness Interferometer is dependent upon the size of the Straightness Mirror. The standard mirror provides for measurements with up to 2 meters of travel. The allowable lateral excursion range of the Prism is ± 1 millimeter. The system resolution with the standard Straightness Mirror is ± 0.04 micrometer.

Theory of Operation

Refer to Figure 2 and the following explanation.

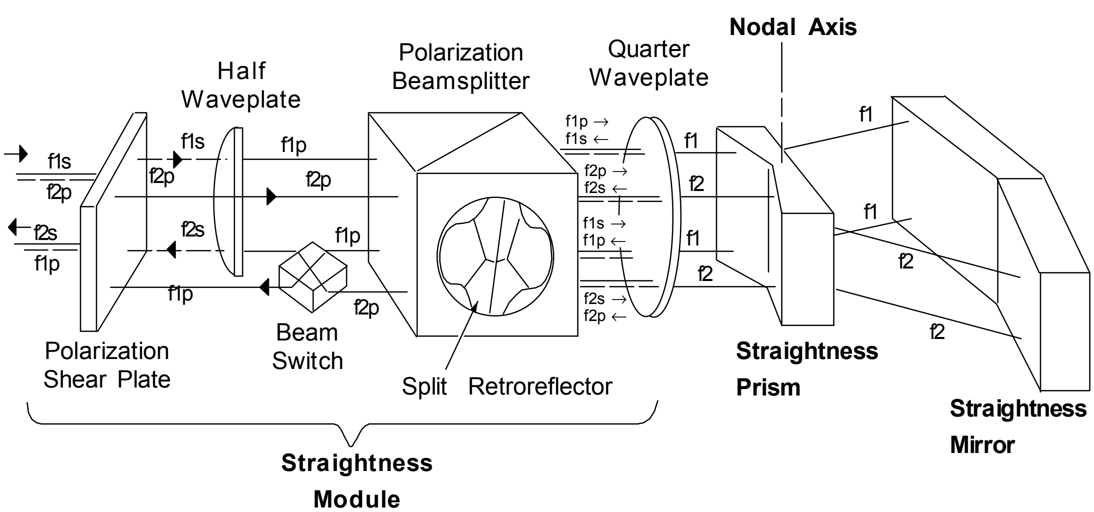


Figure 2 Straightness Interferometer Schematic

The incoming laser beam is comprised of two orthogonally polarized beams, F1 and F2. The combination beam enters one hole in the Beam Translator, which shifts the beam toward the center of the Polarization Shear Plate. The Shear Plate splits the beam into two parallel beams of different polarizations. One of these beams passes through a Half Waveplate, which rotates the beam polarization 90 degrees. Both beams are now identically linearly polarized.

The Polarization Beamsplitter transmits both incoming beams, which become circularly polarized when directed the first time through the Quarter Waveplate. Both beams strike the Straightness Prism and are diverted to the Straightness Mirror, where they reflect back through the Prism to the Quarter Waveplate. With two passes through the Quarter Waveplate both beam's polarizations are rotated 90 degrees; thus, the beams are reflected at the Polarization Beamsplitter and directed to the Split Retroreflector.

The Split Retroreflector reflects both beams back to the Polarization Beamsplitter, where they reflect to the Quarter Waveplate and out to the Prism and the Mirror for the second time. Both beam's polarizations are again rotated 90 degrees with two passes through the Quarter Waveplate and are now transmitted through the Polarization Beamsplitter.

The Beam Switch swaps the locations of the outgoing beams. The polarization of one beam is rotated 90 degrees by the Half Waveplate so that it is orthogonal to the other beam. The beams are then recombined by the Polarization Shear Plate, shifted by the Beam Translator, and output to a detector. Lateral displacement of the Straightness Prism causes the optical path of the one set of beams (measurement leg) to change relative to that of the other set of beams (reference leg). The detector converts the optical signal into an electrical signal.

Straightness displacement is represented mathematically by:

$$d = \frac{N\lambda}{X \sin\theta} \quad (1)$$

where d is displacement, N is the output data from the Measurement Board, λ is the compensated wavelength of the measurement beam in air, X is a representation of the resolution in the Measurement Board electronics (1016 for the Zygo 2/20 system, 1024 for the ZMI 1000, and 4096 for the ZMI 2000), and θ is the deviation angle recorded on the Straightness Prism.

Installation

The Straightness Interferometer Module can be assembled into two different configurations: an up/down configuration and a side/side configuration. Both configuration names relate to the orientation of the Beam Translator; these are shown in Figure 3.

The 7020-01 model is shipped completely assembled in an up/down configuration. If the side/side configuration is required, the up/down configuration can be disassembled and reconfigured.

The 7020-02 model requires the partial disassembly of a DPMI and then the reassembly of the components. Adhere to following cautions and refer to Figure 3 if it is necessary for you to reassemble the Straightness Module.

⚠ **WARNING!**
DO NOT get fingerprints, dirt, oil, or dust on the mirrors, glass, or openings in the interferometer components. Handle the components with care.

Use care when assembling the optical components into different configurations. Improper screw lengths can damage components and obscure the beams.

DO NOT overtighten screws; sufficient torque is obtained with the supplied 3/32-inch Allen wrench. The recommended torque for the interferometer screws is 2.5 inch-pounds (0.3 Newton-meters).

Changing from the Up/down to the Side/side Configuration

1. Remove the screws holding the Polarization Shear Plate to the Half Waveplate. Then remove the screws holding the Half Waveplate to the Beam Switch.
2. Rotate the Half Waveplate 90 degrees counterclockwise and reattach it to the Beam Switch, using two 3/8-inch long socket head screws.

   Note: Refer to Figure 3 for proper orientation of the components.
3. Rotate the Beam Translator and Polarization Shear Plate 90 degrees clockwise, and re-attach it to the Half Waveplate. Tighten the screws after the components are aligned.

Making the Straightness Module from an Existing DPMI

1. Remove the screws holding the Polarization Shear Plate to the Half Waveplate. Then remove the screws holding the Half Waveplate to the Polarization Beamsplitter.
2. Attach the Beam Switch to the Polarization Beamsplitter using two 3/8-inch long socket head screws. Then attach the Half Waveplate to the Beam Switch. Tighten the screws after the components have been aligned and leveled on a flat and clean surface.
3. Attach the Polarization Shear Plate to the Half Waveplate. Tighten the screws after the components are aligned.
4. Remove the Retroreflector from the Polarization Beamsplitter. Then secure the Split Retroreflector in position.

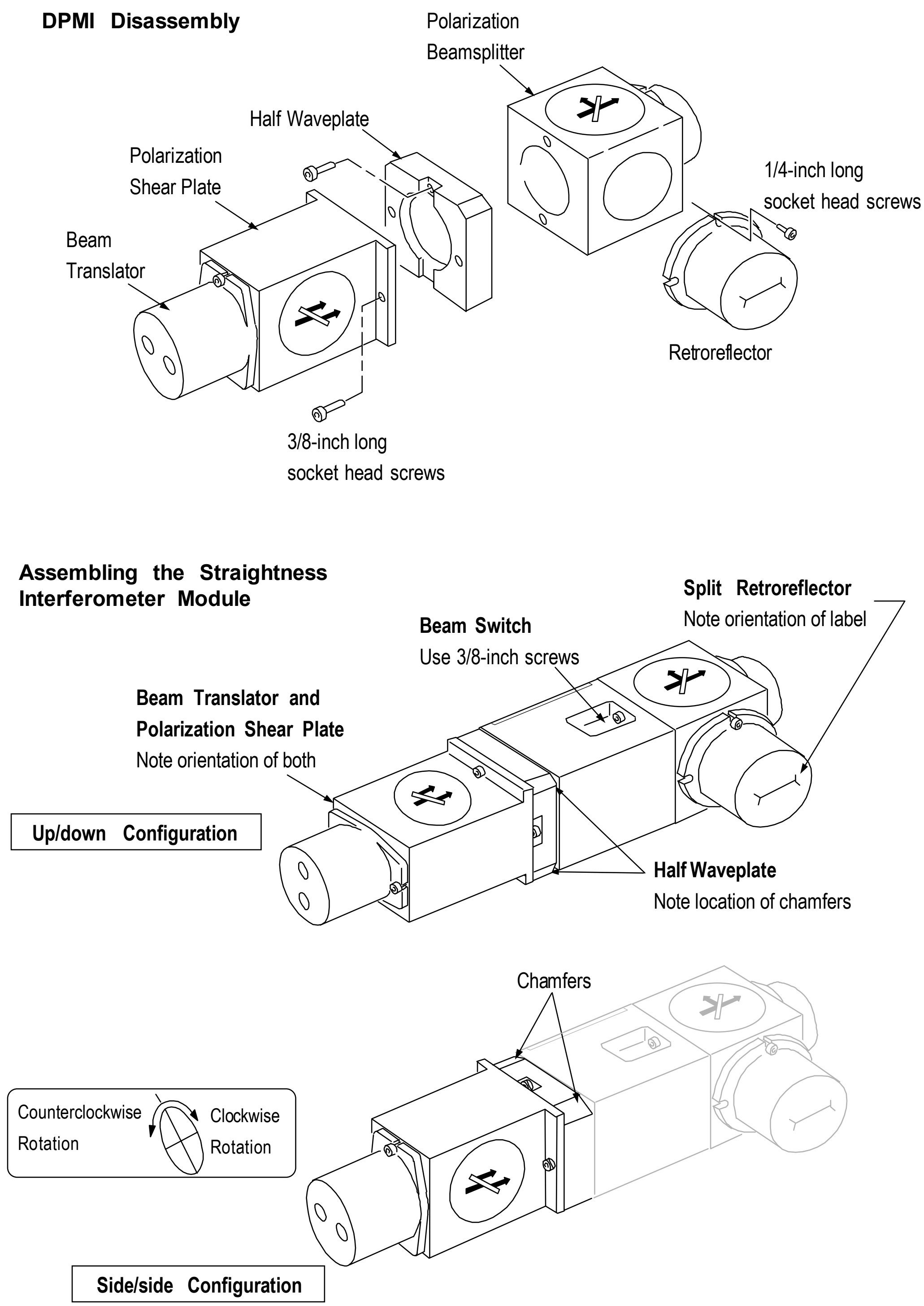


Figure 3 Assembling the Straightness Interferometer

Mounting

In general, the Straightness Interferometer Module, the Straightness Prism, and the Straightness Mirror must be mounted so that the bottoms or sides are parallel or perpendicular to the plane defined by the Laser Head to within ±1 degree. Locate the Interferometer Module so the beams do not become subject to thermal gradients or fluctuations and so it is not subject to machine vibrations.

When performing alignment, it is necessary to adjust the position of the Straightness Interferometer Module, the Straightness Prism, and the Straightness Mirror. For this reason, the Module should be mounted on the Zygo Model 7013 Accessory Mount, the Prism on the Zygo Model 7011 Interferometer Mount, and the Mirror on a user-supplied mount. Mounting of the Module, Prism, and Mirror is shown in Figure 5.

> **Note:** The Straightness Prism has a nodal axis, precisely in the center of the 1.5 inch cube. The straightness measurement is the deviation of this nodal axis. The Prism should be precisely positioned so the nodal axis is located at the point you want the straightness measured.

Because the mounted components have different beam heights, your specific application must be predesigned so the beam heights at the Module, Prism, and Mirror are aligned. The beam heights are shown in Figure 4. The input beam may enter either hole in the Beam Translator of the Straightness Module.

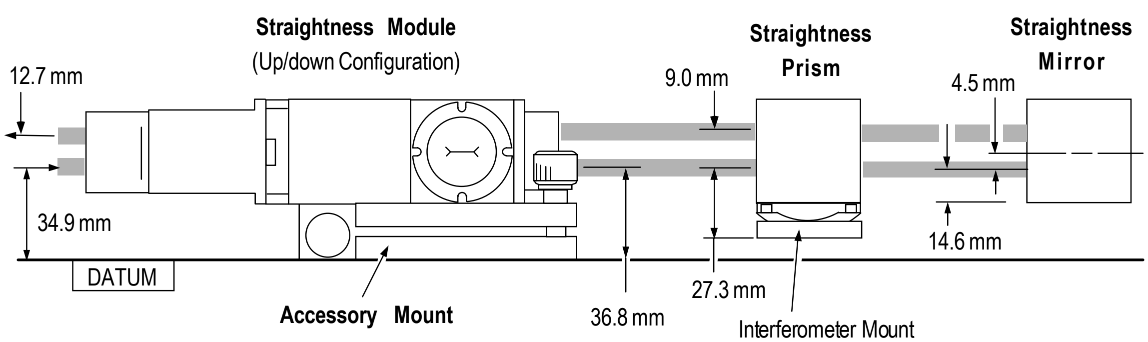


Figure 4 Beam Heights

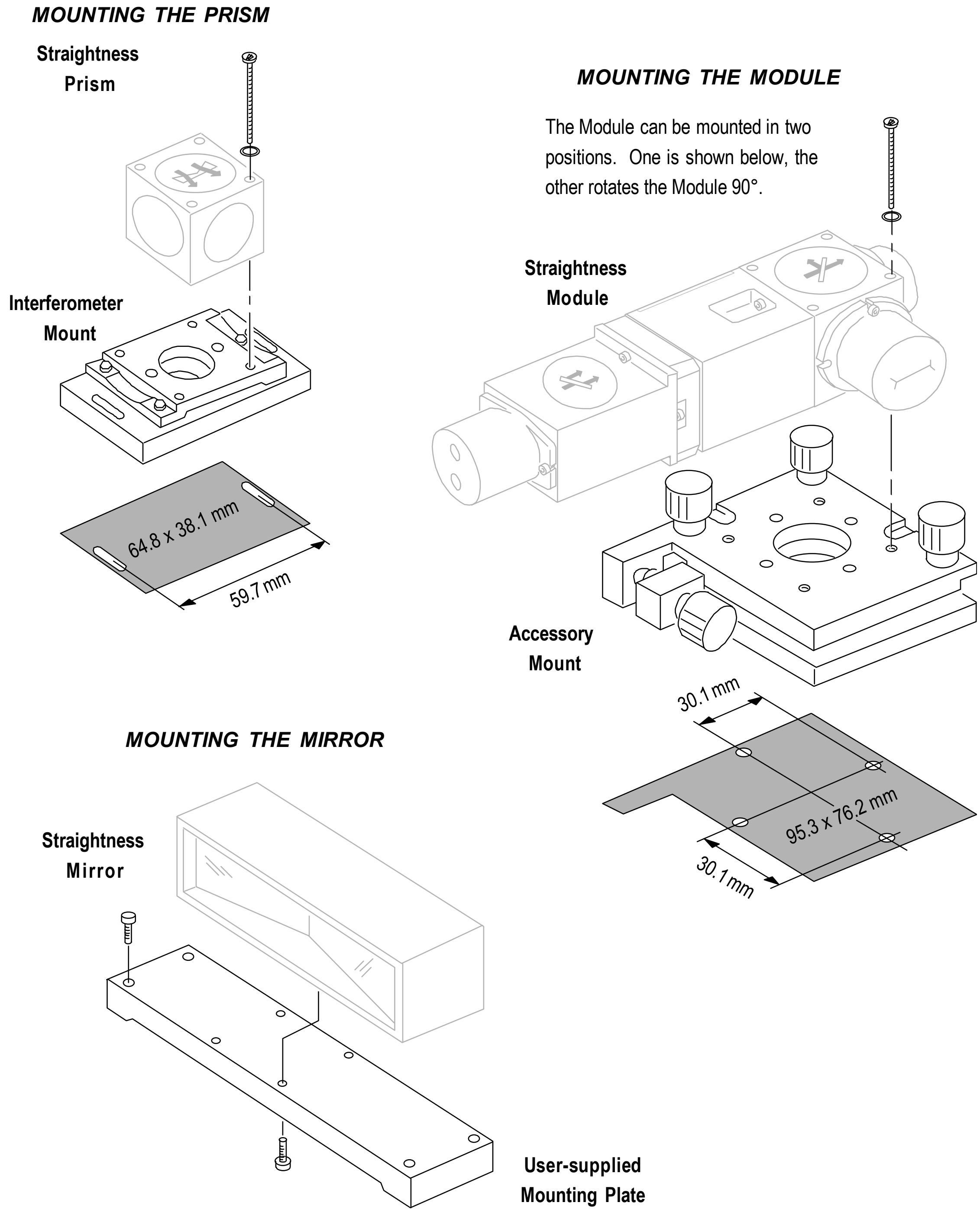


Figure 5 Mounting the Straightness Interferometer Components

Optical Alignment

To achieve the maximum accuracy possible with an interferometer, the entire interferometer system must be properly aligned.

> **Note:** It is recommended that the user have previous experience in optical alignment techniques before aligning the Straightness Interferometer. Alignment requires meticulous effort and repetition of steps.
>
> A plane parallel mirror is included with the Straightness Interferometer to simplify optical alignment.

The following procedures describe the alignment of a one axis Straightness Interferometer system without Fold Mirrors or Beamsplitters.

Aligning the Straightness Prism

Refer to Figure 6.

1. Mount the Straightness Prism on the movable stage. Using mechanical means, adjust the position of the Prism until its input face is perpendicular to the axis of travel.
2. Mount the Laser Head in position. Turn on the Laser Head and allow it to warm up for at least 20 minutes. Then select the small aperture on the Laser Head.
3. Adjust the location of the Laser Head so that the input beam strikes the boundary of the two glass surfaces in the Prism. Adjust the height of Laser Head that the beam is 6.35 millimeters below the midpoint of the Prism.
4. Align the output beam of the Laser Head parallel to the travel axis by performing the following steps:
   a. Position the Alignment Card on the movable stage as close as possible to the Laser Head and adjust the card so that the beam from the Laser Head goes through the pinhole in the card.
   b. Move the stage along the measurement axis. Adjust the position of the Laser Head so the beam goes through the pinhole in the card when the card is close to the Laser Head and also when the card distant.
5. Align the Prism to the input beam by performing the following steps:
   a. Place a Plane Parallel Mirror placed against the front of the Prism.
   b. Place the alignment card in front of the Laser Head so the beam passes through the hole in the card.
   c. Adjust the position of the Prism so that the beam reflected from the mirror is centered in the hole in the alignment card.
6. Ensure that the conditions described in steps 3 through 5 are met.

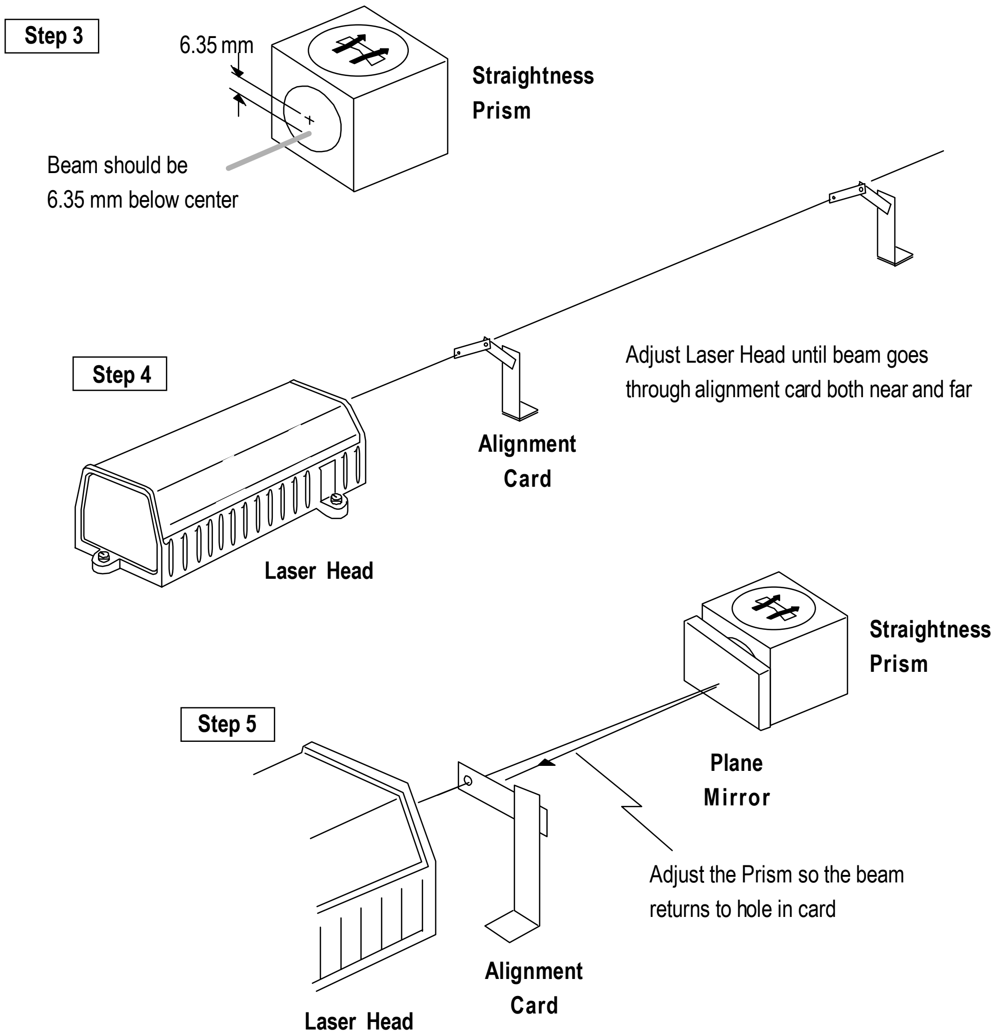


Figure 6 Aligning the Straightness Prism

Aligning the Straightness Interferometer Module Refer to Figure 7.

1. Mount the Module and adjust its position so that the beam from the Laser Head is centered on one of the Beam Translator's apertures.
2. Align the Module to the input beam by performing the following steps:
   a. Place a Plane Parallel Mirror placed against the front of the Module.
   b. Place the alignment card in front of the Laser Head so the small diameter beam passes through the hole in the card.
   c. Adjust the position of the Module so that the beam reflected from the mirror is centered in the hole in the alignment card.
   d. Recheck if the beam is still properly centered in the Beam Translator's aperture, and readjust the Module if necessary.

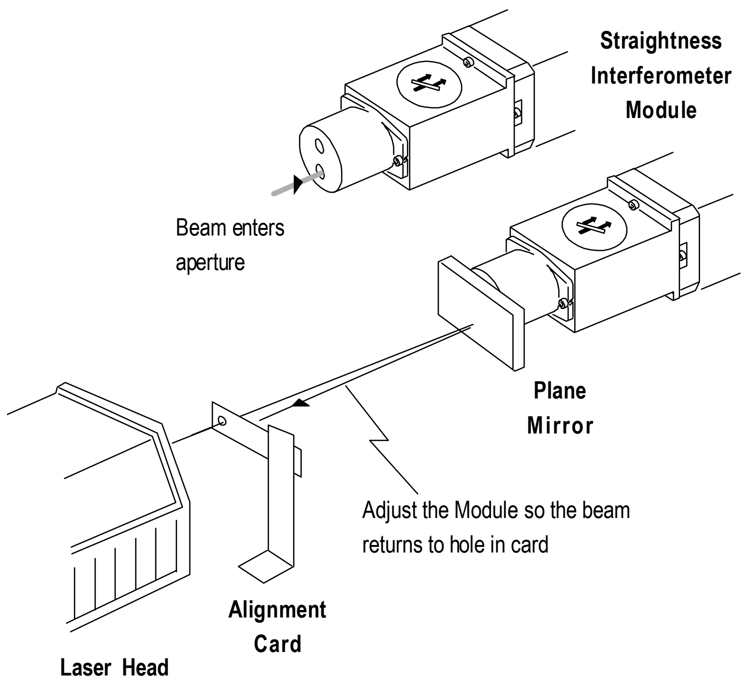


Figure 7 Aligning the Straightness Interferometer Module

Aligning the Straightness Mirror

Refer to Figure 8.

1. Make an alignment screen from a small white card, such as a business card. This card is used for viewing the beams returning from the Straightness Mirror. To make the alignment screen proceed as follows:
    a. Place a white card near the output of the Prism in a location that can be temporarily fixed.
    b. Mark the locations of the two beams on the card. Cut a small 2 millimeter hole at each location.
    c. Position the alignment screen so that the beams pass through the holes. Fix the screen in position with wax or tape.
2. Mount the Straightness Mirror in position. Adjust its location so the two beams strike the Mirror at approximately the same distance from its center and about 4.5 millimeters below the horizontal centerline.
3. Adjust the position of the Mirror so the beams are reflected back through the holes in the alignment screen. Ensure that step 2 is still met. Then secure the Mirror and remove the alignment screen.

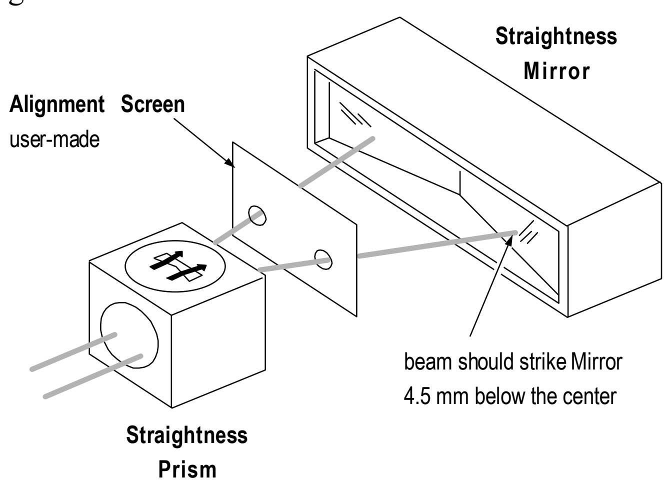


Figure 8 Aligning the Straightness Mirror

Final Alignment

Refer to Figure 9.

Note: The following procedure describes the final alignment of a system that uses a receiver. If you are using a fiber optic pickup, refer to *OMP-0326 ZMI Optic Guide* and the section titled “Optimizing Alignment”.

1. Mount the Receiver or Fiber Optic Pickup in the appropriate user-supplied mount.
2. Select the 6 millimeter (large) laser beam and allow all four beams from the Module to reflect back from the Mirror.
3. Place a piece of translucent tape over the aperture of the Receiver or Pickup. The reference and measurement beams should be visible on the tape. If necessary, adjust the vertical and/or lateral position of the Receiver so that the beams are centered in the aperture. Ensure that the beams are not obstructed.
4. The beam reaching the Receiver or Pickup should be composed of two overlapping beams. Block the beams going to one side of the Straightness Mirror, and then block the beams going to the other side of the Mirror. By looking at the Receiver or Pickup when blocking the beams, you can tell if both sets of beams are reaching and overlapping each other completely. If the two beams do not overlap properly at the Receiver, or Pickup make a slight adjustment of the Mirror.
5. Remove the tape. Verify that the Signal OK LED is on.

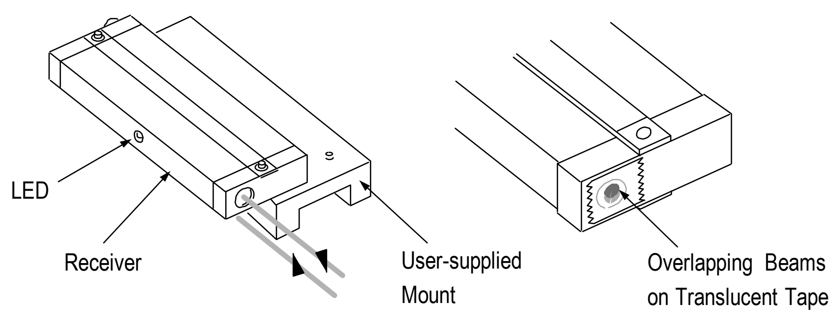


Figure 9 Final Alignment, Receiver

System Accuracy and Installation Considerations

The overall accuracy of any laser interferometry system is dependent upon a number of factors, including: 1) the wavelength stability of the laser beam, 2) polarization mixing error in the laser head, 3) the accuracy of the electronics, 4) system design errors, 5) alignment induced errors, 6) stability of the environment, and 7) interferometer errors.

The sections that follow discuss only the interferometer errors associated specifically with the Straightness Interferometer.

> **Note:** For a general discussion of accuracy and installation factors, refer to Chapter 5 of *OMP-0326 ZMI Optics Guide*, or Chapter 11 of *OMP-0220 ZYGO 2/20 Operation and Reference Manual*.

Straightness Mirror Flatness

An uncertainty results from out of flatness of the Straightness Mirror. The Straightness Prism's motion causes the beams to translate on the Straightness Mirror surface. Errors in the Mirror are sensed by the interferometer. The magnitude of the straightness uncertainty may be as great as 1 micrometer. This value depends on the actual flatness of the Mirror and the length of travel of the Straightness Prism.

Alignment Errors

Another measurement error is caused when the beams output from the Prism do not strike the Mirror at normal incidence. For an angular misalignment of 0.5 degree, and a lateral deviation of the Prism nodal axis of 0.2 millimeters, the error in the measurement would be ~15 nanometers.

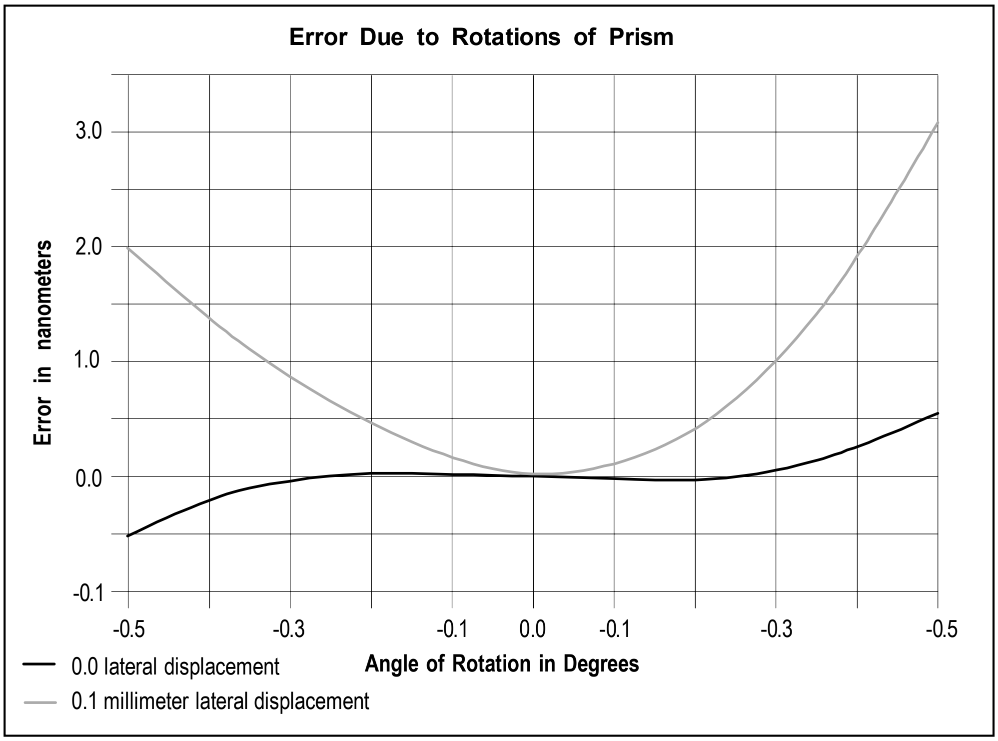
Beam Deviation Error

The beam deviation (θ) is used in equation 1. Zygo's uncertainty in measuring θ is $\pm$ 40 seconds of arc. The resulting uncertainty in straightness is approximately linear. The calculated error measuring of 0.2 millimeter straightness is 2.43 micrometers.

Straightness Prism Rotations

Rotation of the Straightness Prism about an axis parallel to the nodal axis can cause a measurement uncertainty. If this rotation is centered about the nodal axis, the uncertainty is minimized. Note that the nodal axis is identified in Figure 2.

The chart below shows the effect of rotation of the Prism about the nodal axis for two displacements in a plane perpendicular to the nodal axis. Rotations about other axes parallel to the nodal axis can be considered a rotation about the nodal axis plus a translation in the plane perpendicular to the nodal axis. As shown in the chart, rotations about the nodal axis do not cause a significant error.



Maintainence

Zygo optical components are ruggedly designed and built to deliver optimal performance. All the optical surfaces should be kept completely free of contaminants. Improper or unnecessary cleaning can damage optics.

⚠ **WARNING!**
Zygo is not responsible for any damage that occurs to an optical component as a result of improper cleaning.

Guidelines for handling and cleaning optical components:

- Do not attempt to clean the optical surface of any component unless experienced in optical cleaning techniques.
- Never touch the optical surfaces of the components with your bare hands. Acids and salts in the skin can cause permanent degradation of surfaces.
- Store unused optical components in the supplied plastic bags and product boxes.
- The exterior metal cells of the components may be cleaned with a cloth dampened with a mild cleaning solution, such as methanol.

Note: Detailed cleaning procedures for optical components are located in Chapter 6 of *OMP-0326 ZMI Optics Guide*, and Chapter 8 of *OMP-0220 ZYGO 2/20 Operation and Reference Manual*.

Straightness Interferometer

Configuration	Zygo Part Number	Model
Standard	6191-0331-01	7020
DPMI Conversion Kit	6191-0331-02	7020K

Dimensions: See Figure.

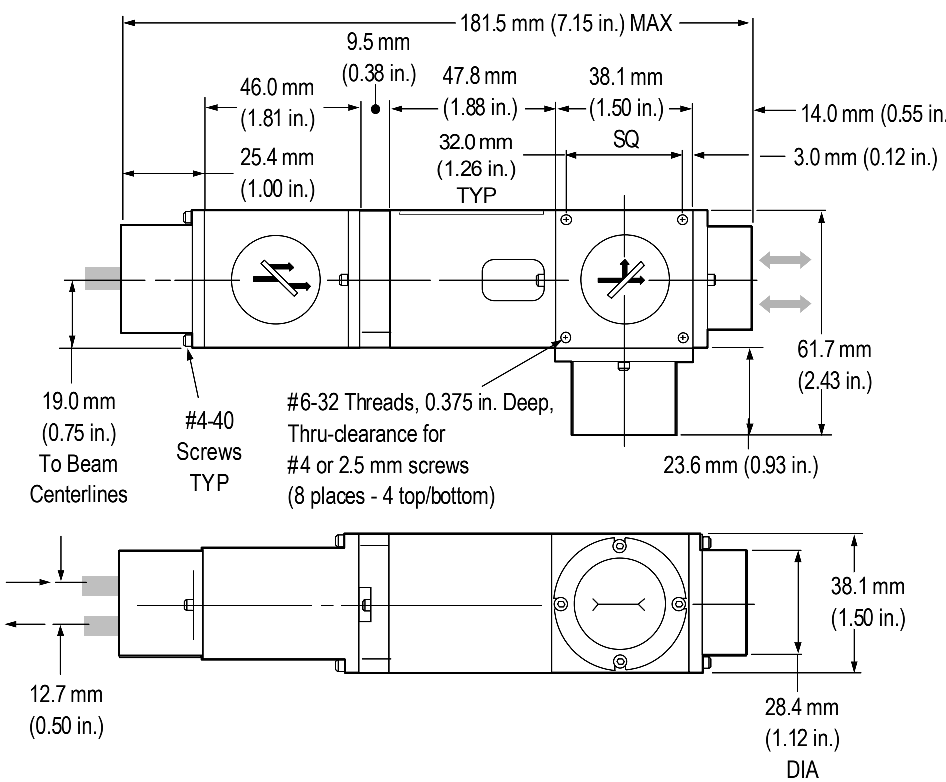
Weight: 825 grams (29.1 oz)

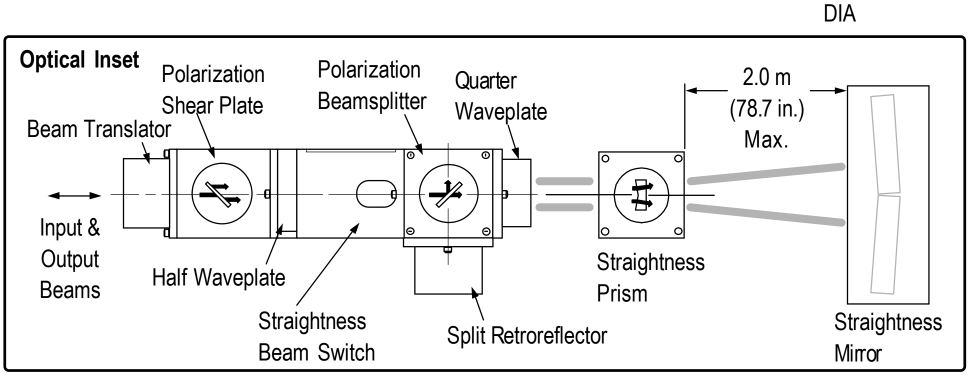
Components Included:
Polarization Beamsplitter, Half Waveplate, Quarter Waveplate, Polarization Shear Plate, Beam Translator, Split Retroreflector, Beam Switch Prism, Straightness Prism, Straightness Mirror

Materials:
Housing: Magnetic Stainless Steel
Optics: BK-7 and Crystalline Quartz
Adhesives: Vacuum Grade -- low volatility

Optical: See Inset.
Measurement Range: ± 1 mm
Straightness Resolution (nominal):
0.0395 μm (ZMI 1000)   0.01 μm (ZMI 2000)
Maximum distance between Straightness Prism and Straightness Mirror: 2.0 m (78.1 in.)

Optical Signal Efficiency: ≥ 30%





Straightness Interferometer (continued)

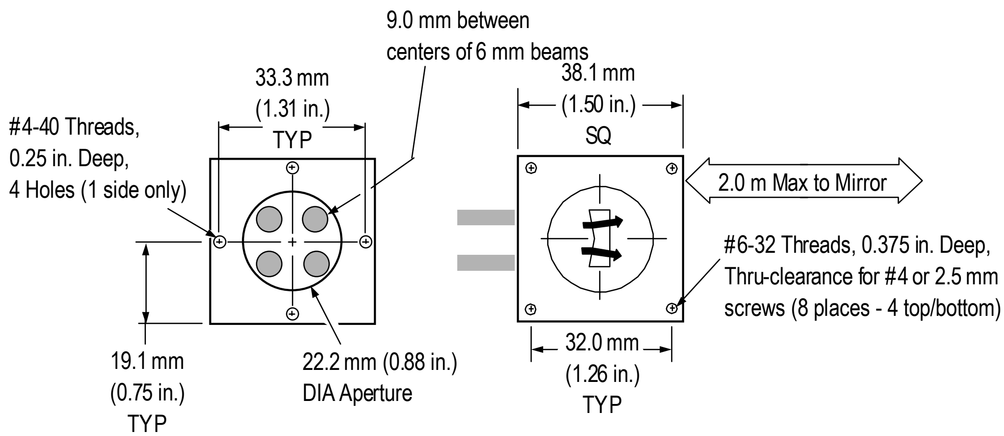
Straightness Prism and Mirror

Zygo Part Number: 6191-0264-01
Dimensions: See Figure.
Weights:
238 grams (8.4 oz) Prism
755 grams (26.6 oz) Mirror

Materials:
Housing: Magnetic Stainless Steel
Optics: BK-7 (Prism),
Zerodur or Fused Silica (Mirror)
Adhesives: Vacuum Grade -- low volatility

Note: The Straightness Prism and Straightness Mirror are a “matched” set.

Prism



Mirror