7C

Agilent 10706A Plane Mirror Interferometer

Description

This subchapter describes:

- the Agilent 10706A Plane Mirror Interferometer
- the Agilent 10723A High Stability Adapter

The Agilent 10706A Plane Mirror Interferometer can be used with a plane mirror reflector to obtain distinct advantages.

The unique contribution of the Agilent 10706A Plane Mirror Interferometer (see Figure 7C-1) is its tolerance of angular misalignment of the plane mirror reflector. A simple linear interferometer would require a plane mirror to remain perpendicular to the laser beam within several arc-seconds; otherwise, the interference fringes would not be detectable. With the Agilent 10706A interferometer, angular deviations of minutes of arc are commonly acceptable.

With this measurement optic, interference fringes are detectable even though the measurement beam is not at perfect right angles to the mirror. Therefore, several valuable applications become possible. For example, in a two-axis laser measurement system, the X reflector can be allowed to move in the Y direction without affecting the signal strength or the X measurement. Consequently, both reflectors of a two-axis system can be mounted on the same moving part to minimize Abbé offset error. Defining the measuring point as the point where the two axis beams cross, the measurement is essentially independent of yaw of the moving stage. Such a design is shown in Figure 7C-2.

Compare the system shown in Figure 7C-2 to a two-axis system using linear or single-beam interferometers. The X-axis retroreflector must be mounted on a part of the stage that moves in the X direction and not in the Y direction. Also, the Y-axis retroreflector must be mounted on a different part of the stage that is allowed to move in the Y direction and not in the X direction. These constraints prevent two-axis measurements from being made on the same part of the stage. Further, there will be some geometry error in the system if it is not perfectly rigid.

The Agilent 10706A Plane Mirror Interferometer uses a flat mirror reflector. For X-Y stage applications, the user must provide the mirror(s). For single-axis applications, the Agilent 10724A Plane Mirror Reflector may be used. This device is described more fully in Chapter 9, “Accessories.”

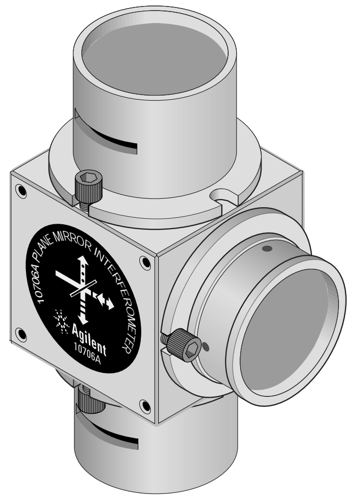


Figure 7C-1. Agilent 10706A Plane Mirror Interferometer

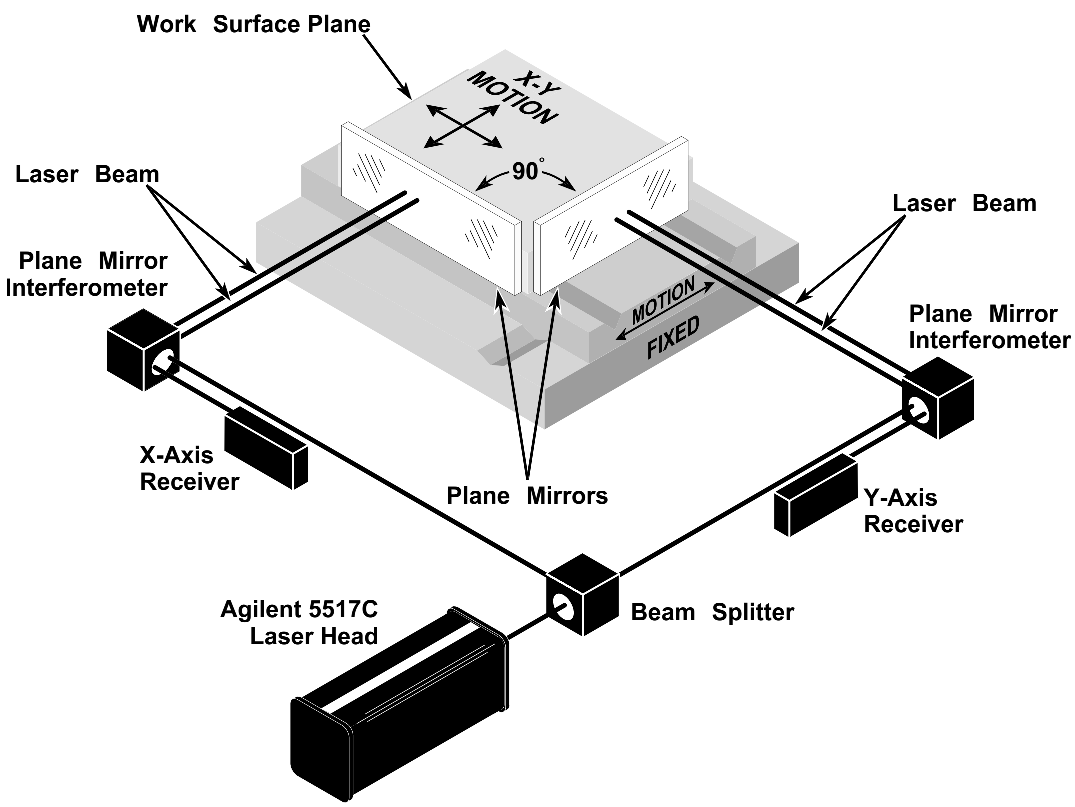


Figure 7C-2. X-Y Stage measurement with Agilent 10706A Plane Mirror Interferometer

In an Agilent 10706A interferometer, the measurement beam travels twice between the interferometer and the plane mirror, thus the resolution of the measurement is twice that of the linear or single beam interferometers. With 32X electronic resolution extension, this results in a resolution of λ /128 (5 nanometers or 0.2 microinch) with the plane mirror interferometer, compared to λ /64 (10 nanometers or 0.4 microinch) with the linear or single beam interferometers.

The Agilent 10706A interferometer can be converted to the Agilent 10706B high-stability interferometer configuration by retrofitting the Agilent 10706A with an Agilent 10723A High Stability Adapter. Information for the conversion is contained later in this subchapter. The Agilent 10706B interferometer and Agilent 10723A adapter are described in subchapter 7D of this manual.

Laser beam paths

For purposes of this discussion, the laser beam input is through the interferometer's Aperture B, and the output to the receiver is through Aperture A (see Figure 7C-3).

After entering Aperture B, the beam from the laser head is split at the surface of a polarizing beam-splitter.

One frequency (f_B) enters the interferometer's reference path, which directs it to the reference cube corner and then out to the receiver.

The second frequency (f_A) enters the interferometer's measurement path. This beam is transmitted out to the plane mirror reflector and is reflected back on itself (Figure 7C- 3). The interferometer's quarter-wave plate causes the polarization of the return frequency to be rotated through 90° so that $f_A \pm \Delta f$ is reflected out a second time where it is Doppler shifted again. The polarization of $f_A \pm 2\Delta f$ is rotated again through 90° so it is now transmitted back to the receiver. Resolution doubling is inherent because of the double Doppler shift.

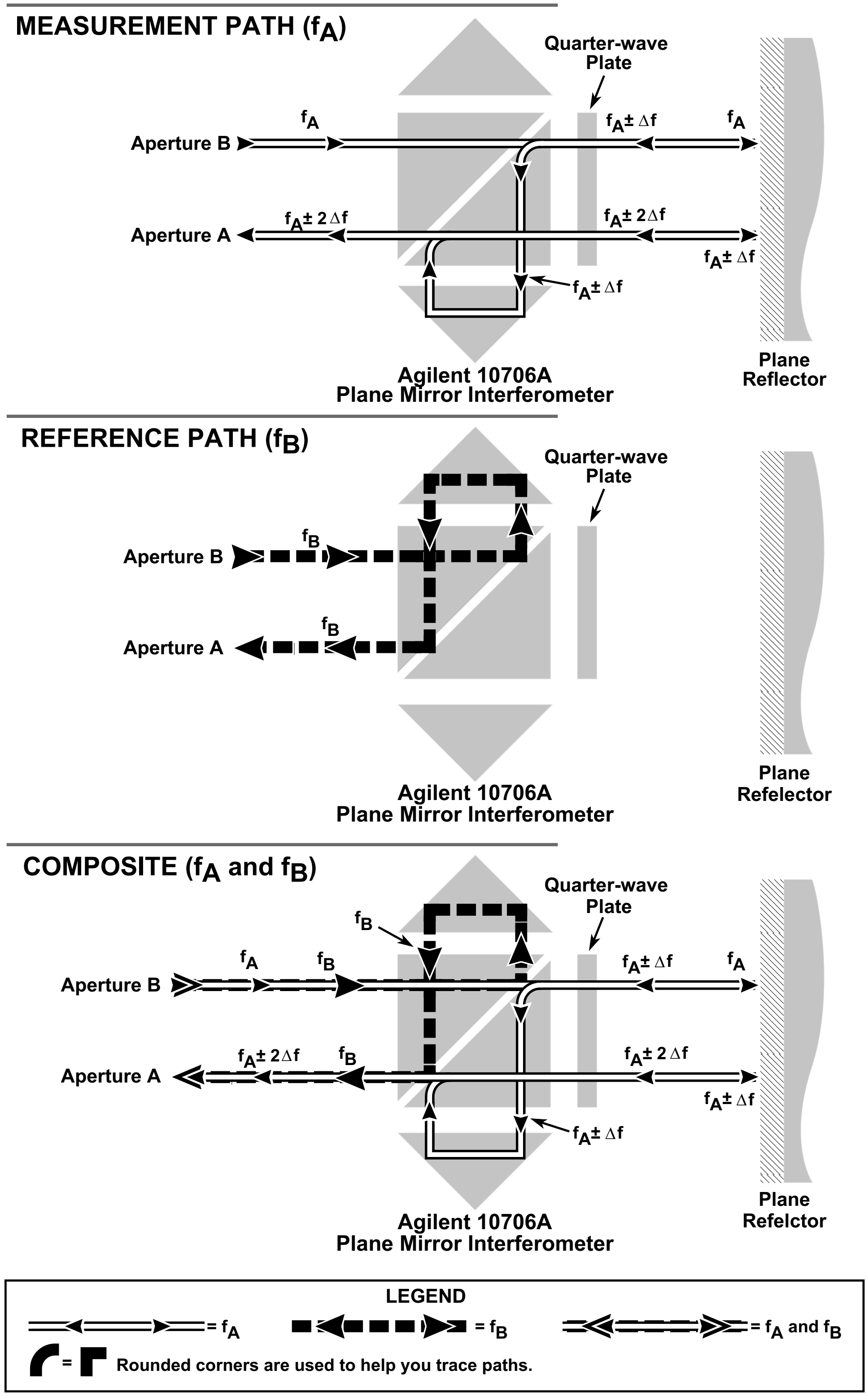


Figure 7C-3. Plane mirror interferometer laser beam path

Special Considerations

Differential measurements

A general discussion of differential measurements using laser interferometers is given in the introduction to this section.

To use the Agilent 10706A interferometer in a differential configuration: 1) replace the reference cube Corner (or high-stability adapter) with the Agilent 10722A Plane Mirror Converter, and 2) attach the reference plane mirror to the reference surface of interest. This is shown in Figure 7C-4. Be sure to install and align the reference reflector the same as you would the measurement reflector.

Turned configuration

To reduce the number of beam benders for this application, the interferometer can be configured to turn the beam. This is done by interchanging the reference cube corner and the plane mirror converter Figure 7C-5 shows a reconfigured Plane Mirror Interferometer that turns the beam. Note the location of the plane mirror converter with respect to the arrows on the label.

In this configuration (Figure 7C-5), the laser measurement beam is turned to the left. When the measurement beam needs to be turned to the right (as in Figure 7C-6, X-axis), the interferometer is rotated 180° about the incoming beam's optical axis.

NOTE

With this change in configuration, the measurement direction sense will change (see the "Effect of Optics on Measurement Direction Sense" information in Chapter 3, "System Design Considerations," of this manual).

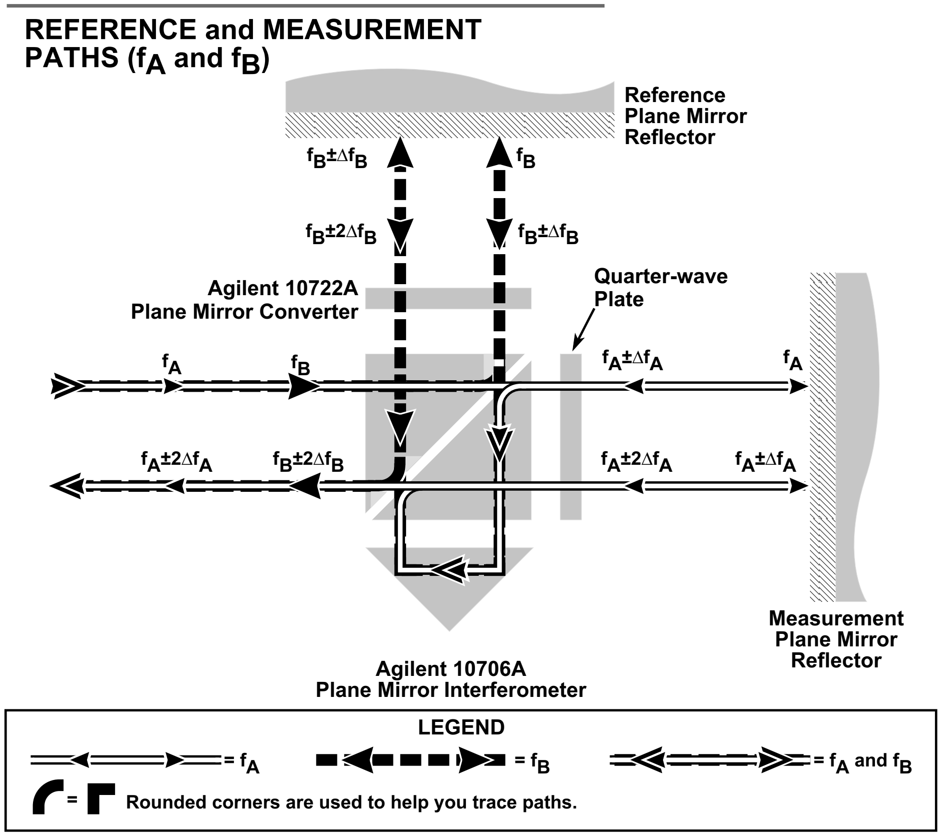


Figure 7C-4. Differential measurements with the Agilent 10706A

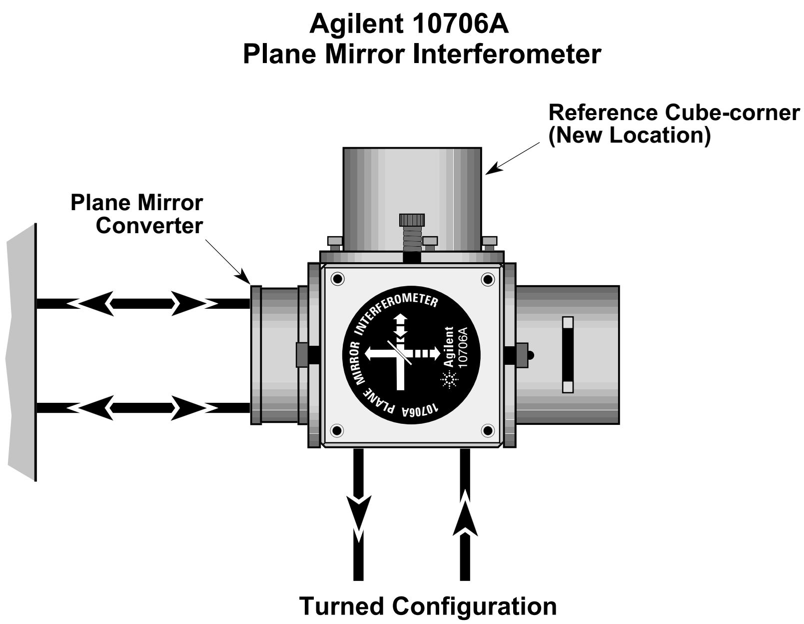


Figure 7C-5. Differential measurements with the Agilent 10706A

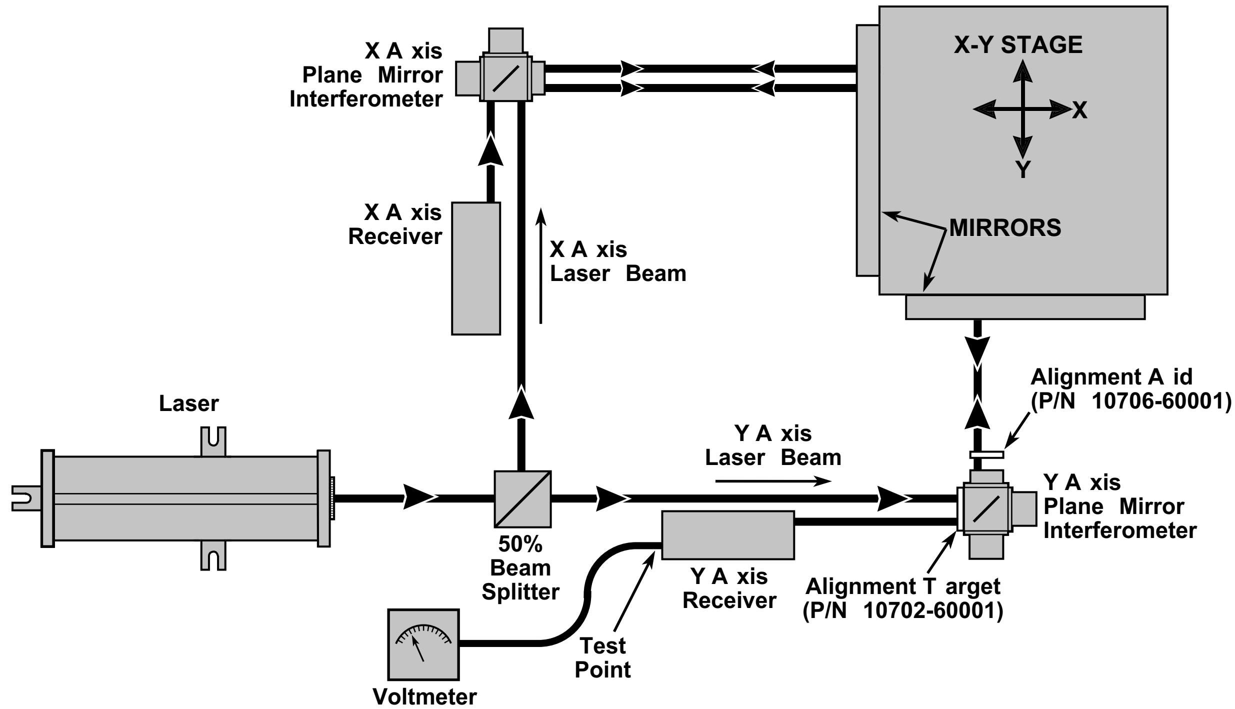


Figure 7C-6. Agilent 10706A Plane Mirror Interferometer—alignment

Mounting

Adjustable mounts

The Agilent 10711A Adjustable Mount provides a convenient means of mounting, aligning, and securely locking the Agilent 10706A interferometer in position. Since the mount allows some tilt and yaw adjustment, the need for custom fixturing is minimized. The mount allows the interferometer to be rotated about its centerline, simplifying installation.

Fasteners

The Agilent 10706A interferometer is supplied with English mounting hardware, which is required to fasten it to its adjustable mount.

Installation

Pre-installation check

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).
- ☐ You must supply the plane mirror reflectors if the Agilent 10724A Plane Mirror Reflector will not work for your installation. See Chapter 15, “Accuracy and Repeatability,” Chapter 6, “Beam-Directing Optics,” or Chapter 7, “Measurement Optics,” in this manual for mirror specifications.
- ☐ 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. (Ideally, you want to be able to translate beam in two directions and rotate beam in two directions for each interferometer input. This typically takes two adjustment optics with proper orientations.)
- ☐ Be sure to allow for transmitted beam offset of beam splitters (Agilent 10700A and Agilent 10701A) in your design. (See the offset specifications under the “Specifications” heading at the end of this subchapter.)

Alignment

General

This procedure covers specifically the alignment of the Agilent 10706A Plane Mirror Interferometer as applied to an X-Y positioning system using flat mirrors as measurement reflectors.

It is assumed that:

1. the mirror surfaces are flat to within the tolerances required for operation of the plane mirror interferometer. (Refer to the recommendations under the "Specifications" heading at the end of this subchapter), and
2. the mirror surfaces have been aligned perpendicular to each other and their respective directions of travel.

Figure 7C-6 illustrates the most common 2-axis plane mirror interferometer installation. The interferometers have been configured to turn the beam in this example.

The alignment of the plane mirror interferometer uses the autoreflection alignment technique described in Chapter 4, “System Installation and Alignment,” of this manual. In most cases, the accuracy demands of the X-Y positioning devices used, along with the relatively short travels encountered, dictate that the high accuracy alignment technique described in the autoreflection alignment procedure be used.

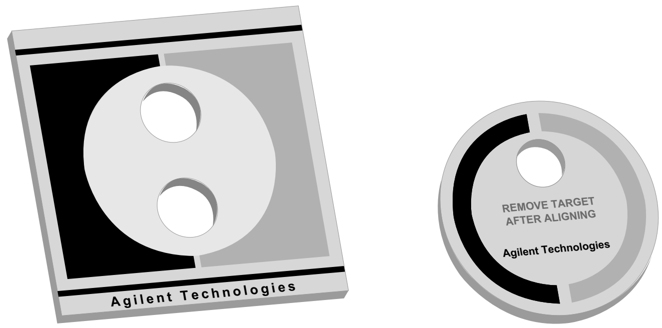
The alignment procedure follows the instructions for using the alignment aids, which begin below.

Alignment aids

Figure 7C-7 shows the two alignment aids supplied with the Agilent 10706A Plane Mirror Interferometer:

- Alignment Target, Agilent Part Number 10702-60001
- Alignment Aid, Agilent Part Number 10706-60001

Both aids are magnetic to simplify positioning on the interferometer.



Alignment Target
P/N 10702-60001

Alignment Aid
P/N 10706-60001

Figure 7C-7. Agilent 10706A Interferometer — alignment aids

The Alignment Target (Agilent Part Number 10702-60001) is used on the input side of the interferometer to properly position the beam in the aperture.

The Alignment Aid (Agilent Part Number 10706-60001) is placed on the output aperture of the interferometer to allow autoreflection. This aid contains a quarter-wave plate to reflect the measurement beam back on itself and return it to the laser head without offset.

The Alignment Aid must be positioned to transmit the primary measurement beam. This is the first of the two measurement beams that travel between the Agilent 10706A interferometer and the plane mirror reflector. To identify the primary beam, block one of the two measurement beams; if the other beam also disappears, the beam you blocked is the primary measurement beam.

Alignment procedure

This procedure describes the alignment of Agilent 10706A Plane Mirror Interferometers used on an X-Y stage application. (See Figure 7C-6.)

NOTE Steps 1 through 11 constitute the Y-axis alignment.

1 Place the interferometer alignment target on the laser side of the Y-axis plane mirror interferometer and place the receiver alignment target on the receiver (Figure 7C-8, position 1). Place a piece of opaque

material such as translucent tape between the Y-axis plane mirror interferometer and the mirror.

2 Adjust the laser head until the laser beam 1) passes through the 50% beam splitter, 2) enters one hole of the interferometer alignment target, and 3) exits the other hole centered on the receiver alignment target. Fasten the laser head securely.

3 Select the small aperture of the laser head and install the alignment aid on the output of the plane mirror interferometer in the correct orientation (the hole transmits the first pass of the measurement beam to the measurement mirror). Remove the opaque material from between the plane mirror interferometer and the mirror.

ALIGNMENT TARGET FOR RECEIVER

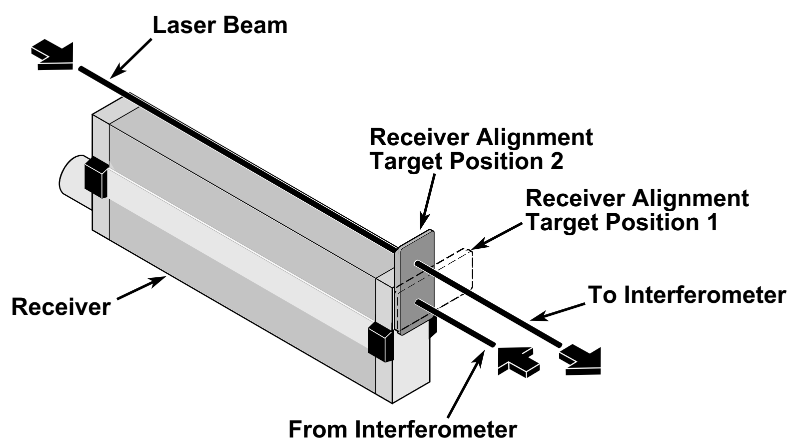


Figure 7C-8. Receiver and receiver alignment target

4 The laser beam will now exit the interferometer and be reflected by the mirror back upon itself into the interferometer. Pitch and yaw the plane mirror interferometer until the beam reflected from the mirror returns upon itself through the plane mirror interferometer and back to the small aperture of the laser head. Slight lateral translations of the plane mirror interferometer may be required to ensure that the reference beam is still centered on the receiver alignment target. If the distance between the mirror and the laser head is at least 0.5 meter (20 inches), the formula below determines the cosine error based on the offset of the return beam at the laser head.

$$E = \frac{S^2}{8D^2}$$

where:

E is the cosine error value

S is the offset of the returning beam (in micrometers or microinches)

D is the measured (displacement) distance (in millimeters or inches)

For example, if the distance measured is 600 mm and it results in a 1.2-mm (1200-micrometer) offset, cosine error (E) will be:

$$E = \frac{(1200)^2}{(8) \times (600)^2} = 0.5\text{ppm (0.5 micrometer per meter of travel)}$$

NOTE For high accuracy alignment or for installations where there is less than 0.5 meter (20 inches) between the laser and mirror, perform steps 5 through 7.

5 Remove the receiver target and plane mirror interferometer alignment target and select the large aperture of the laser head. Do not remove the plane mirror interferometer alignment aid on the output side of the plane side of the plane mirror interferometer.

6 With a fast-responding voltmeter (preferably an analog type) attached to the receiver test point, pitch and yaw the plane mirror interferometer until a signal is received on the receiver. (The voltmeter will suddenly jump to some value greater than 0. 25 volt.) This is a critical adjustment and may initially require great care.

7 Adjust the plane mirror interferometer in pitch and yaw until the voltmeter reading (which may be fluctuating) is maximum. Now carefully readjust the interferometer until the voltage reading suddenly drops back down to about 0.3 volt.

NOTE The alignment should be adjusted such that the voltage reading from the receiver test point occurs just below the sudden jump up in voltage. If the alignment is fixed to sustain this peaked voltage, system operation will be degraded.

This aligns the laser beam to within ±1.2 arc-minutes to the direction of travel, resulting in a cosine error of approximately 0.05 ppm. That is 0.05 micron per meter of travel (0.05 microinch per inch) of cosine error.

8 Fasten the plane mirror interferometer (Y-axis) securely, preserving the alignment.

9 Monitor the voltage reading along the complete travel of the stage (y-axis). The voltage should not jump up to the previous maximum voltage reading. If the voltage does jump, readjust the interferometer until the voltage reading suddenly drops back down to about 0.3 volt.

10 Remove the plane mirror interferometer alignment target and alignment aid. The reference beam and the measurement beam must be centered on the receiver alignment target.

11 Remove the receiver alignment aids and rotate the turret on the laser head to the large aperture. Verify that the LED indicator on the receiver is lighted and the voltage at the receiver test point is between 0.6 and 1.3 Vdc.

NOTE Steps 12 through 20 constitute the X-axis alignment.

12 With the laser head turret in the large aperture position, place the plane mirror interferometer alignment target on the laser head side of the X-axis plane mirror interferometer and the receiver alignment target on the receiver (Figure 7C-8, position 1). Place a piece of opaque material between the X-axis plane mirror interferometer and the mirror.

13 Pitch and yaw the 50% beam splitter until the laser beam enters one hole of the plane mirror interferometer alignment target and exits the other, centered on the receiver alignment target (do not adjust the laser head). Slight lateral translations of the 50% beam splitter may be necessary to ensure there is no beam clipping. Fasten the 50% beam splitter securely.

14 Select the small aperture on the front turret of the laser head and install the alignment aid on the output of the plane mirror interferometer in the correct orientation (the hole transmits the first

pass of the measurement beam to the measurement mirror). Remove the opaque material from between the plane mirror interferometer and the mirror.

15 The laser beam now exits the interferometer and is reflected by the mirror back upon itself and into the interferometer. Pitch and yaw the plane mirror interferometer until the beam reflected from the mirror returns through the plane mirror interferometer and back to the small aperture of the laser head. Slight lateral translations of the plane mirror interferometer may be required to ensure that the reference beam is still centered on the receiver alignment target. If the distance between the mirror and the laser head is at least 0.5 meter (20 inches), the formula given earlier in this alignment procedure will determine the cosine error based on the offset of the return beam at the laser.

NOTE For high accuracy alignment or for installation where there is less than 0. 5 meter (20 inches) between the laser and mirror, perform steps 16 through 18.

16 Remove the receiver alignment target and plane mirror interferometer alignment target and select the large aperture of the laser head. Do not remove the plane mirror interferometer alignment aid on the output side of the plane mirror interferometer.

17 With a fast-responding voltmeter attached to the receiver’s test point, pitch and yaw the plane mirror interferometer until a signal is received on the receiver. (The voltmeter will suddenly jump to some value greater than 0.25 volt.) This is a critical adjustment and may initially require great care to achieve the desired result.

18 Adjust the plane mirror interferometer in pitch and yaw until the voltmeter reading (which may be fluctuating) is maximum. Now carefully readjust the interferometer until the voltage reading suddenly drops back down to about 0.3 volt.

NOTE The alignment should be adjusted such that the voltage reading from the receiver test point occurs just below the sudden jump up in voltage. If the alignment is fixed to sustain this peaked voltage, system operation will be degraded.

This aligns the laser beam to within ±1.2 arc-minutes to the direction of travel, resulting in a cosine error of approximately 0.05 ppm. That is 0.05 micron per meter of travel (0.05 microinch per inch) of cosine error.

19 Fasten the plane mirror interferometer (X-axis) securely, preserving the alignment.

20 Monitor the voltage reading along the complete travel of the stage (x-axis). The voltage should not jump up to the previously peaked voltage reading. If the voltage does jump, readjust the interferometer until the voltage reading suddenly drops down to about 0.3 volt.

21 Remove the plane mirror interferometer alignment target and alignment aid. The reference beam and the measurement beam must be centered on the receiver alignment target.

22 Remove the receiver alignment aids and rotate the turret on the laser head to the large aperture. Verify the LED indicator on the receiver is lighted and the voltage at the receiver test point is between 0.6 and 1.3 Vdc.

Specifications and Characteristics

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

Plane mirror systems have a basic optical resolution of one quarter wavelength (0. 158 micron, 6.23 microinches).

Using electronic resolution extension, the system resolution is increased significantly. Depending on the system, an additional resolution extension factor of 32 (for Agilent 10885A and 10895A) or 256 (for Agilent 10897B and 10898A) is usually available.

Interferometer	Fundamental Optical Resolution	System Resolution 1 (see NOTE)	System Resolution 2 (see NOTE)
Agilent 10706A	λ /4 (158.2 nm, 6.2 µin)	λ /128 (5.0 nm, 0.2 µin)	λ /1024 (0.62 nm, 0.024 µin)

NOTE

The system resolution 1 is based on using 32X electronic resolution extension. This is available with the Agilent 10885A and Agilent 10895A electronics.

The system resolution 2 is based on using 256X electronic resolution extension. This is available with the Agilent 10897B and Agilent 10898A electronics.

Agilent 10706A Plane Mirror Interferometer Specifications

Weight: 308 grams (10.9 ounces)

Dimensions: see figure below

Materials Used: same as Agilent 10702A Interferometer

Optical Efficiency: (including a 98% efficient plane mirror reflector):

Typical: 70%

Worst Case: 54%

Fundamental Optical Resolution: λ /4

Non-linearity Error: <2.2 nm (0.09 µin)

PLANE MIRROR (MEASUREMENT MIRROR) SPECIFICATIONS
Reflectance: 98% for 633 nanometers at normal incidence (minimum 80%)

Flatness: Depending on the application and accuracy requirements of the application, mirror flatness may range from λ /4 to λ /20; i.e., 0.16 to 0.03 µmeters (6 to 1.2 µinches).

NOTE: Flatness deviations will appear as measurement errors when the mirror is translated across the beam. Mount should be kinematic so as not to bend mirror. If accuracy requirements demand it, mirror flatness might be calibrated (scanned and stored in the system controller) to be used as a correction factor.

Optical Surface Quality: 60 — 40 per MIL-0-13830

MIRROR ALIGNMENT REQUIREMENTS VS DISTANCE:

Maximum Angular Misalignment: Depends on distance between interferometer and plane mirror.

Typical values are:

±6 arc-minutes for 152 mm (6 inches)

±3 arc-minutes for 305 mm (12 inches)

±1.5 arc-minutes for 508 mm (20 inches)

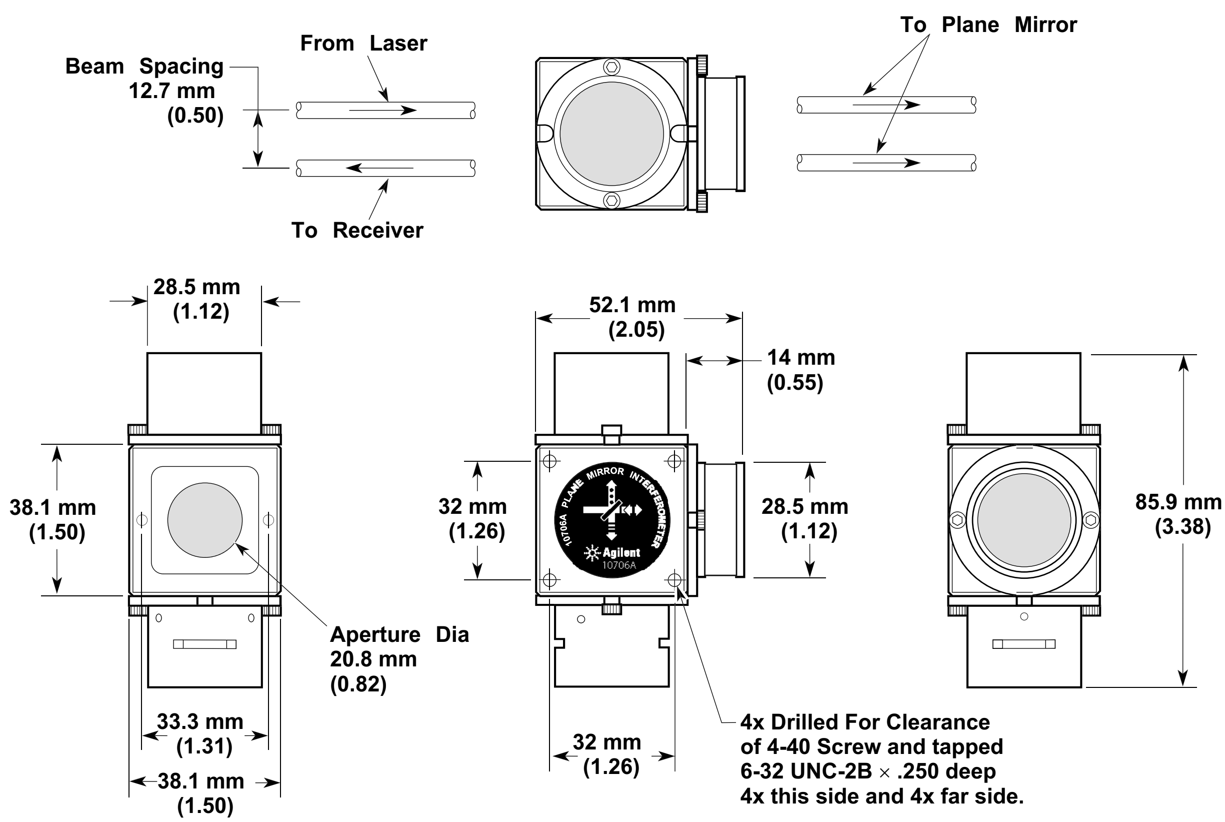


Figure 7C-9. Agilent 10706A Plane Mirror Interferometer — dimensions

Agilent 10722A Plane Mirror Converter Specifications

Weight: 34.3 grams (1.2 ounces)

Dimensions: see figure below

Materials Used:

Housing: 416 Stainless Steel

Optics: Optical Grade Glass

Clear Aperture: 0.900 in

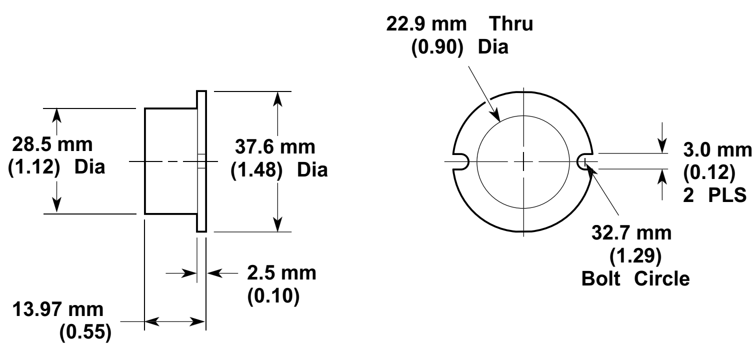


Figure 7C-10. Agilent 10722A Plane Mirror Converter — dimensions

Agilent 10723A High Stability Adapter Specifications

Weight: 48.8 grams (1.7 ounces)

Dimensions: see drawings below

Materials Used:

Housing: Stainless Steel

Cap: Plastic (Nylon)

Optics: Optical Grade Glass

Adhesives: Low Volatility (Vacuum Grade)

For Specifications of an upgraded Agilent 10706A (replacement of reference cube cCorner with Agilent 10723A), see Agilent 10706B Specifications (in subchapter 7D of this manual).

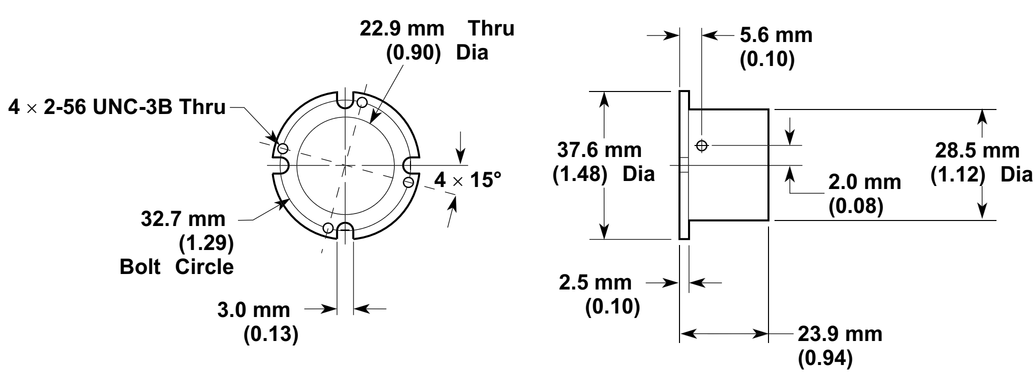


Figure 7C-11. Agilent 10723A High Stability Adapter — dimensions

Agilent 10724A Plane Mirror Reflector Specifications

Weight: 50 grams (1.8 ounces)

Dimensions: see figure below

Materials Used: 416 Stainless Steel

Reflectivity: 98% at 633 nanometers at normal incidence

Flatness: λ /10 (at 633 nanometers)

Installed Angular Adjustment Range: Pitch/Yaw 1° configurations

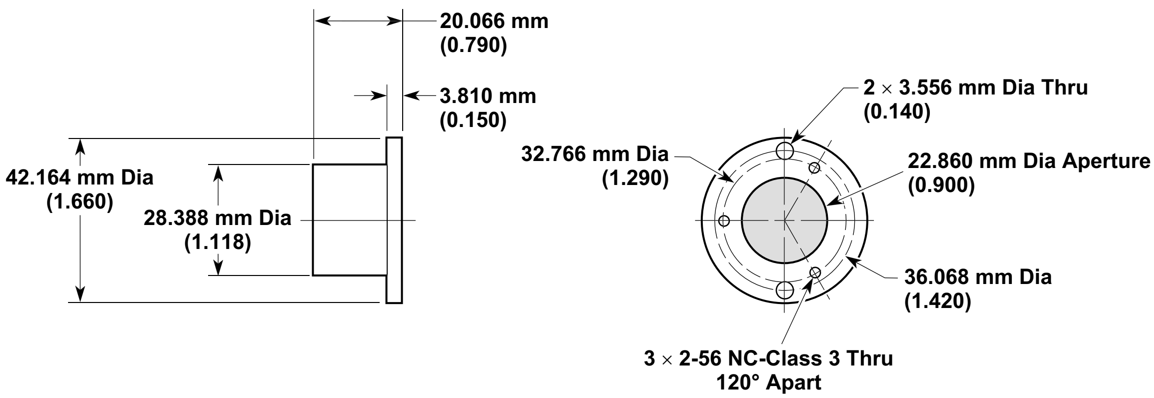


Figure 7C-12. Agilent 10724A Plane Mirror Reflector — dimensions

Converting to High-Stability Plane Mirror Interferometer

General

The Agilent 10706A Plane Mirror Interferometer can be converted to a version having improved thermal stability equivalent to the Agilent 10706B High Stability Plane Mirror Interferometer by replacing the REFERENCE cube corner with an Agilent 10723A High Stability Adapter (see Figure 7C-12).

Instructions for the conversion are given below.

To convert an Agilent 10706A Plane Mirror Interferometer to the Agilent 10706B configuration

NOTE The Agilent 10723A adapter MUST be installed in place of the REFERENCE cube corner on the Agilent 10706A interferometer. If it is inadvertently installed on the other side, the thermal stability will become worse. Refer to Figure 7C-13 for the proper installation orientation.

1 Refer to Figure 7C-13 and positively identify the position in which to install the Agilent 10723A adapter. Note that in either configuration, the Agilent 10723A adapter replaces the REFERENCE CUBE-CORNER (Agilent 10703A Retroreflector).

2 Remove the REFERENCE CUBE-CORNER and store it in a safe place.

3 Refer to Figure 7C-13. If the interferometer is in the straight-through configuration, proceed to step 5 and install the Agilent 10723A adapter using the mounting screws that were used to mount the Reference Cube-Corner.

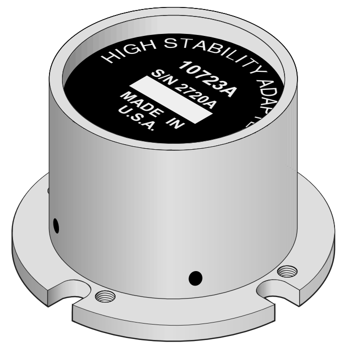
If the interferometer is in the turned configuration, use the new hardware supplied with the Agilent 10723A adapter to mount the adapter as described in step 4.

4 Using the hex key provided, install the four 2-56 × 3/16 inch long screws into the holes on the flange of the Agilent 10723A adapter housing. Be sure they do not protrude through the flange.

Equip both 4-40 × 1/2 inch long mounting screws with a compression spring and use them to install the Agilent 10723A adapter in place of the removed Reference Cube-Corner. Either set of mounting slots may be used to attached the High Stability Adapter to the interferometer.

Tighten both mounting screws until the head of each just begins to compress the spring. Then tighten each screw two turns to properly compress each spring.

Continue to step 6.



Agilent 10723A
High Stability Adapter

Figure 7C-13. Agilent 10723A High Stability Adapter

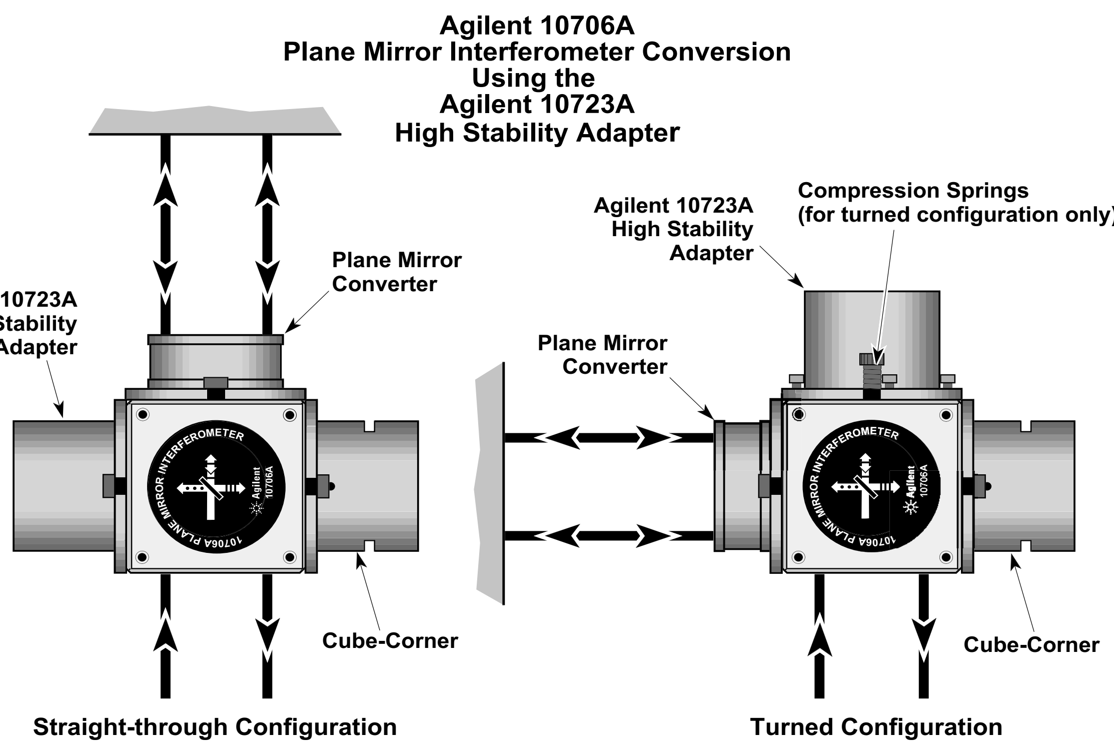


Figure 7C-14. Agilent 10706A Conversion Using the Agilent 10723A

5 Install the Agilent 10723A High Stability Adapter in place of the removed reference cube corner. Either set of mounting slots may be used to attach the High Stability Adapter to the interferometer.

6 Refer to Figure 7C-13. Locate and remove the PLANE MIRROR CONVERTER.

7 The black plastic bezel under the plane mirror converter must be removed to allow access for an Alignment Aid during setup. The bezel is secured with silicone adhesive, but can be easily removed. Place the blade of a small screwdriver under the lip of the bezel and pry the bezel out. PRY THE SCREWDRIVER AWAY FROM THE BEAM SPLITTER GLASS, TAKING CARE THAT IT DOES TO COME IN CONTACT WITH OR SCRATCH THE OPTIC. Discard the bezel.

8 Replace the plane mirror converter that was removed in step 4.

This completes the conversion. The converted interferometer must be realigned as described in the alignment sections for the Agilent 10706B High Stability Plane Mirror Interferometer in subchapter 7D of this manual.

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