ZMI 500 Series
Interferometer System
With 510 Measurement Board
OMP-0429J

zygo®

Zygo Corporation
Laurel Brook Road
P.O. Box 448
Middlefield, Connecticut 06455-0448

Telephone: (860) 347-8506
Fax: (860) 346-4188
E-mail: inquire@zygo.com
Website: www.zygo.com

ZYGO CUSTOMER SUPPORT

For help within North America, please use the contacts listed below. For help in other countries, please contact your local Zygo representative. Be sure to supply the instrument model and serial number, and the software version.

PHONE	Monday - Friday, 8 a.m. - 8 p.m. (Eastern Standard Time) (800) ZYGO NOW (800) 994-6669 *or* (860) 704-5191
FAX	(860) 346-4188
INTERNET	www.zygo.com support@zygo.com
WRITE	Zygo Corporation Laurel Brook Road P.O. Box 448 Middlefield, CT 06455-0448 Attn: Customer Support

MANUAL REVISION INFORMATION

The document (OMP) number and the applicable revision letter for this manual appear on the title page. The publication date appears below.

Revision	Publication Date	Revision	Publication Date
original	November 1998	F	May 2000
B	January 1998	G	June 2000
C	January 1999	H	August 2000
D	June 1999	J	January 2002
E	August 1999		

MANUAL NOTATIONS

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

Note: Provides helpful information.

NOTICE: The descriptions, drawings, and specifications contained herein are subject to change. Zygo is not responsible for errors or omissions herein or for incidental damages in connection with the furnishing or use of this information. This document shall not be reproduced, photocopied, or duplicated, in whole or in part, without prior written approval of Zygo Corp.

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.

01/96

CE Notice

Marking by the CE symbol indicates compliance of this Zygo Corp. instrument to EMC (electromagnetic compatibility) Directive and the Low Voltage Directive of the European Union. Such marking indicates that this system meets the following technical standards:

- EN 55011 – “Limits and methods of measurements or radio disturbance characteristics of ISM (Industrial Scientific & Medical) radio frequency equipment.” Class A, for use in typical commercial environments.
- EN 55022 – “Limits and methods of measurements of radio disturbance characteristics of ITE (Information Technology Equipment).” Class A, for use in typical commercial environments.
- EN 50082-1 1992 – “Electromagnetic compatibility generic immunity standard for the residential, commercial and light industrial environments.”
- EN 61010-1 1993 + A2: 1995 – “Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements.”
- EN 60825-1:1994 + A11: 1996 + A2: 2001 – “Safety of laser products—Part 1. Equipment classification, requirements and user’s guide.

A Declaration of Conformity in accordance with the preceding directives and standards has been made and is on file at Zygo Corporation, Middlefield, Connecticut, USA.

Page intentionally left blank

CONTENTS

CONTENTS

System Overview

Chapter 1

In This Chapter

- The ZMI 500 Series Displacement Measuring Interferometer
  - How a DMI Works
- Component Descriptions
- Specifications
- Safety

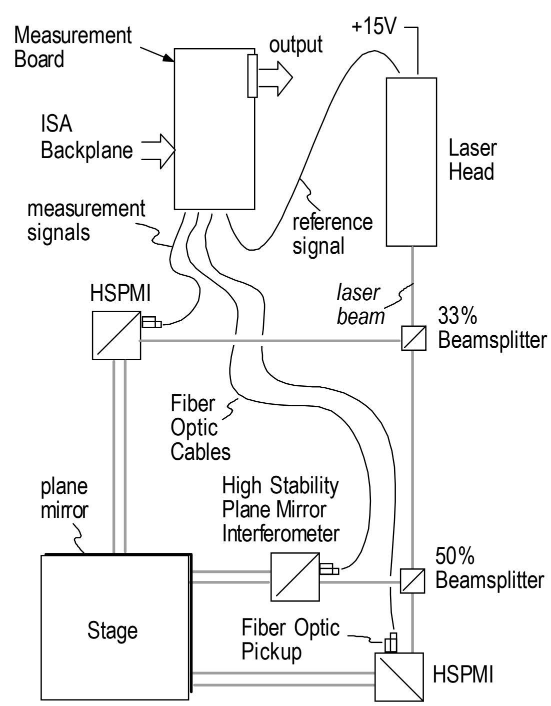
The ZMI 500 Series Displacement Measuring Interferometer

The ZMI 500 Series (2) Displacement Measuring Interferometer (DMI) is a heterodyne laser based displacement measurement solution for high resolution position feedback to a motion control system. A ZMI 500 Series DMI system includes: a Laser Head, a multi-axis Measurement Board, interferometers, beam directing optics, mounts, fiber optic pickups, and fiber optic cables.

How a DMI Works

The light beam emitted from the Laser Head is directed to an interferometer, where the beam is split into two beams. One (reference) beam travels to a fixed optical element. The other (measurement) beam travels to a moving target reflector, such as a plane mirror mounted to a motorized stage. Both beams reflect back to the interferometer and are redirected into a fiber optic pickup, where the beams are recombined and sent to the Measurement Board through fiber optic cables.

Typical Displacement Measuring Interferometer



(1) U.S. patent numbers 4,688,940, and 4,684,828; U.S. and foreign patents pending.
(2) The 500 series refers to Zygo Corporation's Zeeman-split heterodyne laser-based position feedback systems for mid-level performance requirements.

The phase of the recombined optical signal from the interferometer varies with the target reflector position. The ZMI 510 Measurement Board generates a fixed increment quadrature pulse or up/down pulse depending on the direction of phase change.

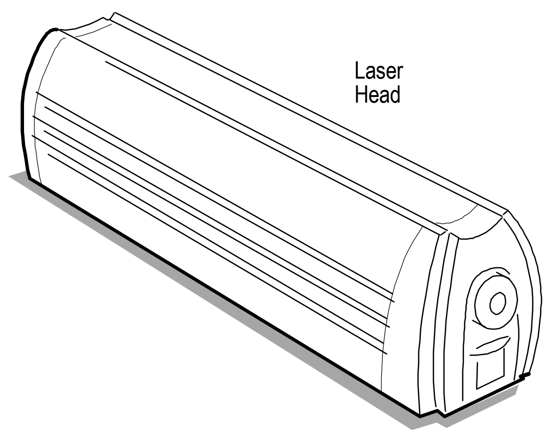
Up pulses are produced by the ZMI 510 Measurement Board when the phase of the measurement signal is advancing relative to the Laser Head reference signal, and down pulses are generated when the phase is retarding. When there is no relative motion of the movable target mirror, the phase difference between the measurement and reference signals remains constant and neither up nor down pulses are produced. The up/down pulses are sent to a user-supplied external counter.

Component Descriptions

The following sections describe the ZMI 500 Series Displacement Measuring Interferometer components. The actual equipment may vary from that shown; see specification pages for more detail. See the specification pages, later in this chapter, for additional information. Items are not drawn to scale.

ZMI Laser Head, Model 7705

The Laser Head supplies the light used as the measurement standard for the DMI system. The Laser Head uses a Helium-Neon, cw, stabilized laser to generate a beam with two frequency components (f1 and f2) that are orthogonally polarized, and offset in frequency by 3.65 MHz.



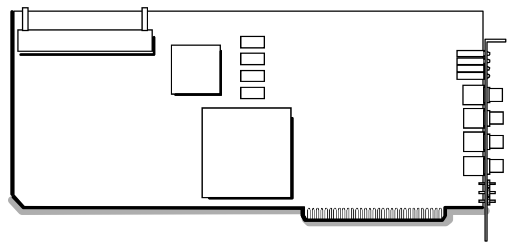
One beam component is used as the measurement beam, while the other becomes the reference beam. The laser tube inside the Laser Head is thermally stabilized to achieve the frequency stability requirements. The 4 millimeter laser beam ($1/e^2$ diameter) exits the Laser Head through an aperture; which also can be set to block the beam output.

A fiber optic connector on the back panel of the Laser Head supplies an optical reference signal for the Measurement Board. The Laser Head requires a user-supplied input power of +15 VDC.

Laser Beam Components

Component	*Polarization*	*Vacuum Wavelength*	*Frequency*
F1	Vertical	632.992 nm	3.65 MHz more than F2
F2	Horizontal	632.992 nm	3.65 MHz less than F1

ZMI 510 Measurement Board



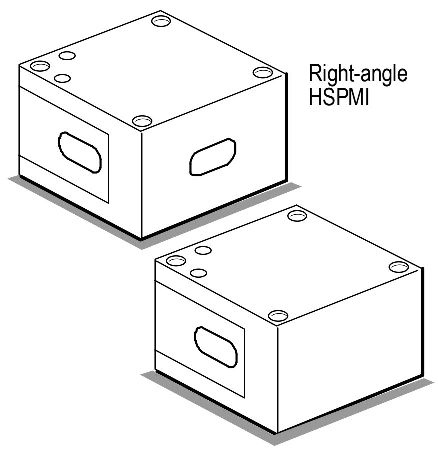
The ZMI 510 Measurement Board combines an optical reference signal from the Laser Head with all optical measurement signals from the interferometers and generates measurement data for up to three axes simultaneously.

The data can be output as either quadrature steps or up/down pulses. The outputs are differentially driven. A quadrature step or a pulse represents a displacement of one resolution unit in one direction. The motion of a movable target mirror causes either up or down output. Direction sense for each axis is selectable by the user.

System resolution and maximum slew rate are also selectable with dip switches. When using the High Stability Plane Mirror (double-pass) Interferometer, approximate measurement capabilities can range from a resolution of 10 nanometers at 160 millimeters per second to 40 nanometers at 500 millimeters per second.

The Measurement Board is mounted in a user-supplied ISA type backplane. Only power is supplied through the ISA connector; there is no ISA bus communication.

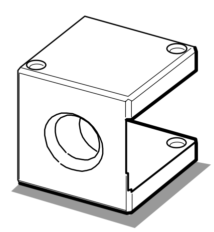
High Stability Plane Mirror Interferometer



The High Stability Plane Mirror Interferometer (HSPMI) is used to measure linear displacement of a plane mirror attached to a movable stage. (This mirror is not supplied as part of the interferometer.) The HSPMI consists of a Polarization Beamsplitter, a Retroreflector, a Quarter Waveplate Plane Mirror, and a Quarter Waveplate. The HSPMI is available in straight-through or right-angle configurations.

The HSPMI includes a Fiber Optic Pickup that attaches to the interferometer cell to provide fiber optic transfer of the measurement signal to the measurement board.

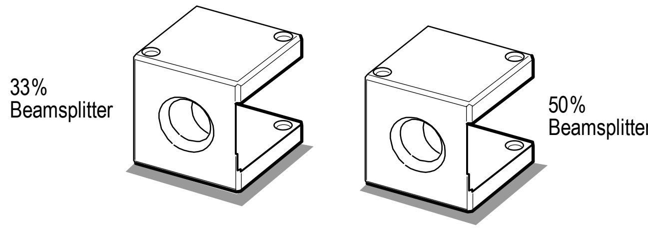
Fold Mirror



The Fold Mirror reflects the laser beam, changing its direction by 90 degrees. It is used wherever it is necessary to bend or redirect the laser beam. Fold Mirrors should not be used in either the measurement or reference beam path of an interferometer.

Beamsplitters

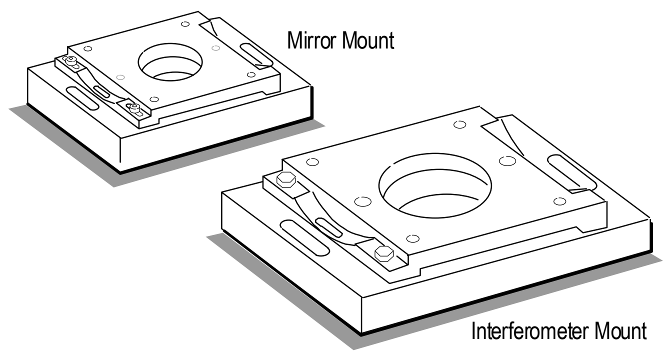
Beamsplitters are used to divide and direct the Laser Head output beam to the interferometers. There are two configurations available, a 33% and a 50% beamsplitter.



The 33% Beamsplitter divides a single laser beam into two perpendicular beams; two-thirds of the beam is transmitted straight and one-third is reflected at 90 degrees. The 50% Beamsplitter divides a single laser beam into two perpendicular beams; one-half of the beam is transmitted straight and one-half is reflected at 90 degrees.

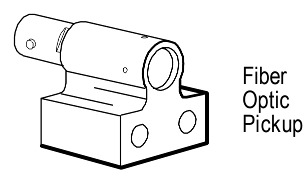
Mounts

Mounts are used to secure the optical components; and to provide for adjustment during optical alignment of the system. There are two configurations available, a Mirror Mount to secure Beamsplitters and Fold Mirrors, and an Interferometer Mount to secure the High Stability Plane Mirror Interferometer.



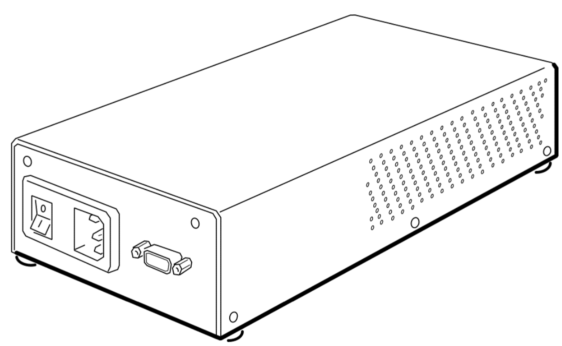
Fiber Optic Pickup

The Fiber Optic Pickup attaches to the interferometer and receives the optical signal, which is transferred to the Measurement Board through a fiber optic cable.



Laser Head Power Supply

This optional universal switching power supply provides ±15 VDC for the laser head.



ZMI Laser Head, Model 7705 P/N 8070-0902-0X

P/N's:
8070-0902-01: >250 µw power output
8070-0902-02: >350 µw power output

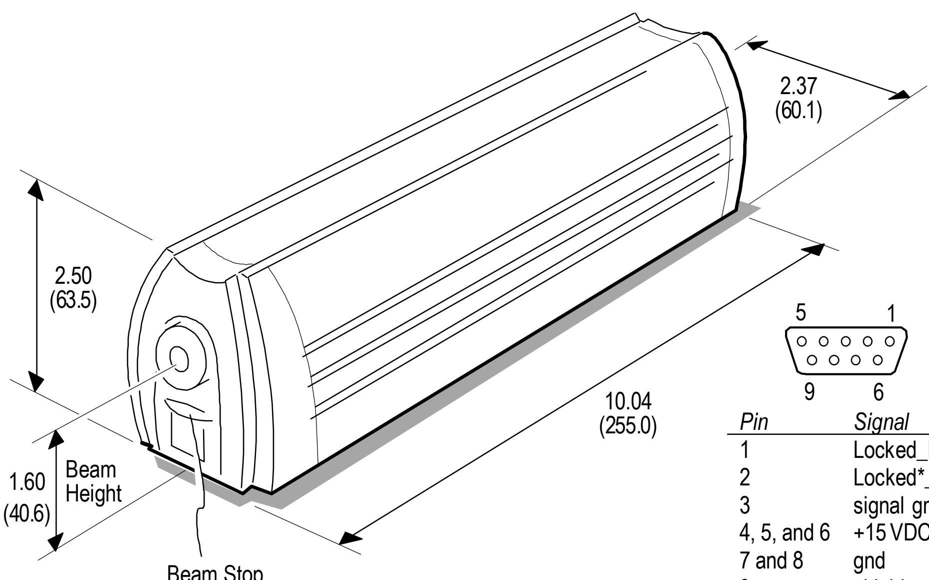
Physical Characteristics:
Dimensions: See Figure
Weight: 2.3 lb (1.0 Kg)
Materials: Aluminum, ABS
Nominal Cable Clearance: 4 in. (102 mm)

Electrical:
Power Requirements (max.):
+ 15 VDC ±0.5V @ 0.6 A
Power Dissipation (max.):
7 watts during typical operation (20°C)
9 watts peak during warm-up
Wavelength Stability Time: ≤15 minutes

Laser Beam Characteristics:
Type: Helium-Neon, cw, two-frequency, linearly polarized
Minimum Beam Power Output:
-01 > 250 microwatts total
-02 > 350 microwatts total
Beam Diameter ($1/e^2$): 4.1 ±0.3 mm (0.16 in.)

Laser Beam Characteristics (continued):
Frequency Difference: 3.6 MHz ±0.3 MHz
Time from turn-on to laser light: < 30 sec typical
Beam Pointing Stability:
0.2 milliradians from cold to hot
Polarization State Deviation from Orthogonality: <1°
Nominal Vacuum Wavelength: 632.992 nm
Vacuum Wavelength Lifetime Accuracy: ± 0.2 ppm
Vacuum Wavelength Stability:
0.01 ppm/1 hour, 0.02 ppm/24 hr
DHHS Laser Safety Classification: Class II laser product conforming to NCDRH regulations.

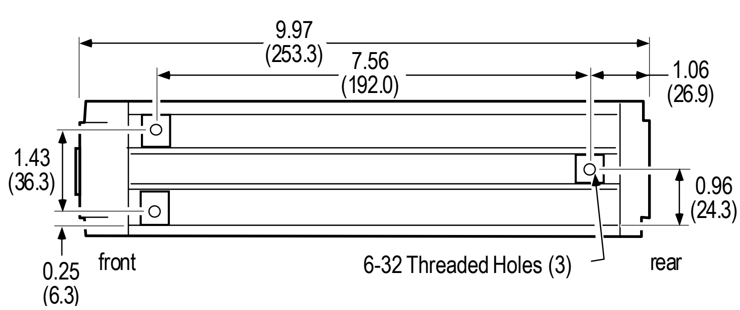
Environmental:
Operating Temperature: 10 to 30°C
Non-operating Temperature: -40 to 75°C
Operating Humidity: 0 to 90% (non-condensing)
Non-operating Humidity:
0 to 90% (non-condensing)
Shock: (non-operating) 11 milliseconds 40 G shock on each of three orthogonal axes.



Pin	*Signal*	
1	Locked_P	
2	Locked*_P	
3	signal gnd	
4, 5, and 6	+15 VDC	minimum wiring requirements
7 and 8	gnd	
9	shield gnd	

Bottom View - Mounting Holes

Mounting screws must not extend into the Laser Head deeper than 5/16-inch (8 mm).



Dimensions shown in inches and (millimeters).

ZMI 510 Measurement Board P/N 8020-0936-03

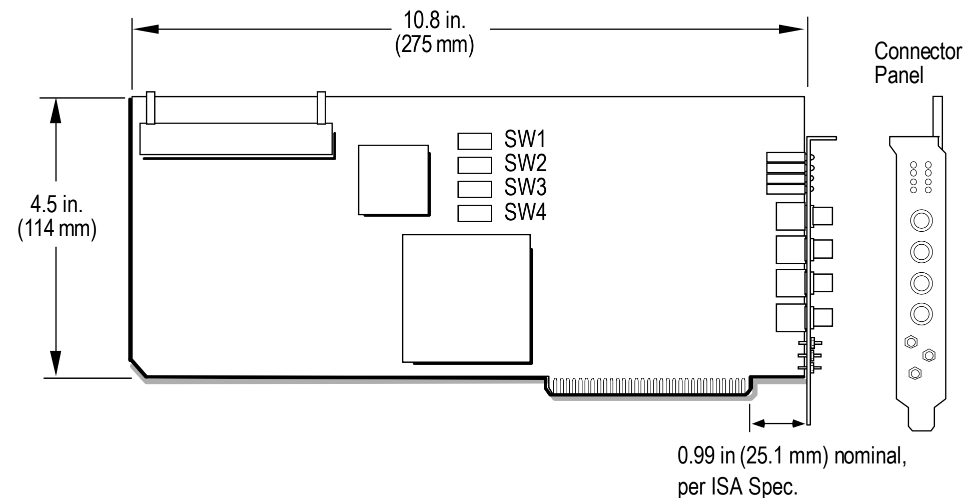
General:
Size: ISA format; see below.
Number of Axes per Board: 3
Power Requirement: +5 VDC ±5% @ 2.0 A max.
Compliance: UL94V0
Recommended Input Intensity for On-board Fiber Optic Detectors: ≥ 5 μW

Data Output:
Position Format:
Quadrature, Up/Down Pulses
Data Transfer: Measurement Board Header, RS-422 (1)
Data Rate:
programmable from 1.8 to 14.6 MHz (nominal)

Performance Specifications:
Position Resolution (maximum):
$\lambda/64$ (9.9 nm) (double pass)
Position Range: ± 10.6 m (double pass)
Velocity Range: ± 0.5 m/sec (double pass)
Maximum Acceleration: 10 g
Linearity Accuracy: ≤ 1.2 LSB 3σ

Operating Environment:
Temperature: 0 to 40° C (32 to 104° F)
Humidity: 0 to 90% (non-condensing)

(1) For details on the output see the National Semiconductor Corporation DS26C31 specification sheet



Connector Pin Out (50-pin AMP 1-104315-9)

Pin	Signal	Pin	Signal	Pin	Signal	Pin	Signal
1	reset in	11	ch3 err	21	ch2 A*	31	shield
2	reset in*	12	ch3 err*	22	shield	32	meas err
3	spare input	13	shield	23	ch2 B	33	meas err*
4	spare input*	14	ch1 A	24	ch2 B*	34	shield
5	ch1 err	15	ch1 A*	25	shield	35	TTL bias
6	ch1 err*	16	shield	26	ch3 A	36	gnd
7	shield	17	ch1 B	27	ch3 A*	37	gnd
8	ch2 err	18	ch1 B*	28	shield	38	gnd
9	ch2 err*	19	shield	29	ch3 B		
10	shield	20	ch2 A	30	ch3 B*	39 thru 50	not used

Beamsplitters, 33%, 50% P/N's 6191-0938-01/02

Dimensions: See Figure.

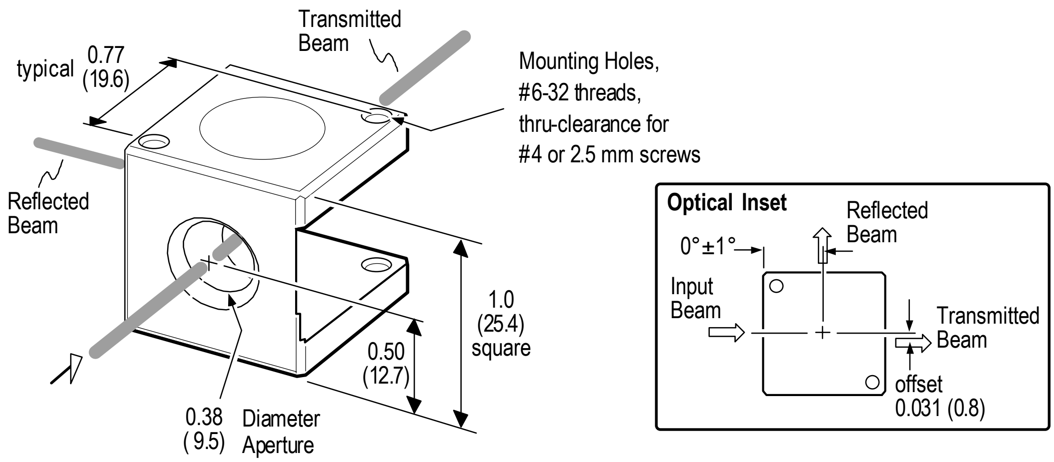
Weight: 60 grams (2 oz)

Materials:
Housing: Stainless Steel
Optics: Fused Silica
Adhesives: Vacuum Grade -- low volatility

Optical: See Inset.
Out-of-parallelism of transmitted beam to input beam: 1° ± 0.5 arc min

Optical Signal Efficiency (max./ min.):

Beamsplitter	*Reflection*	*Transmission*
33%	33/27%	67/62%
50%	50/43%	50/43%



Dimensions shown in inches and (millimeters).

Fold Mirror P/N 6191-0938-03

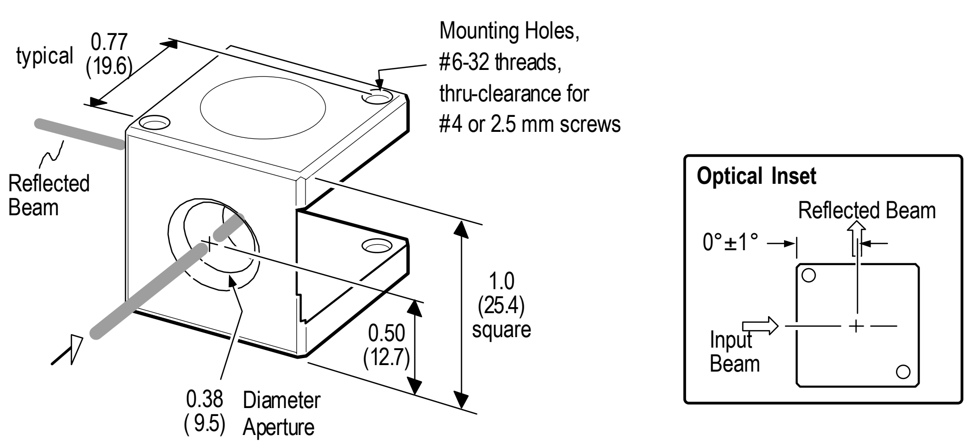
Dimensions: See Figure.

Weight: 60 grams (2 oz)

Materials:
Housing: Stainless Steel
Optics: Zerodur or Fused Silica
Adhesives: Vacuum Grade -- low volatility

Optical: See Inset.

Optical Signal Efficiency (minimum): 97%



Dimensions shown in inches and (millimeters).

High Stability Plane Mirror Interferometer (HSPMI)
P/N 6191-0918-01 (straight-through)
P/N 6191-0918-02 (right-angle)

Dimensions: See Figure.

Weight: 200 grams (7 oz)

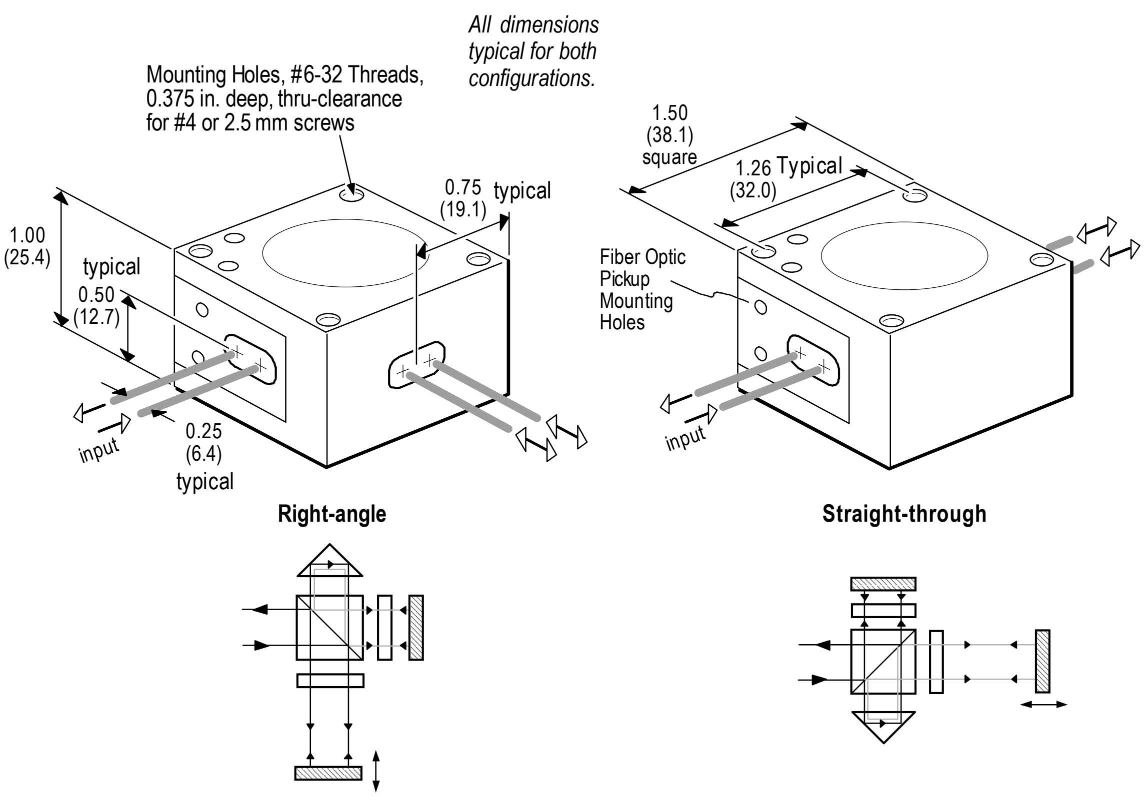
Components Included:
Polarization Beamsplitter, Retroreflector, Quarter Waveplate, Quarter Waveplate Plane Mirror Assembly

Additional Components Required:
Plane Mirror

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

Optical:
Linear Displacement Resolution (nominal): 10 nm
Out-of-parallelism of transmitted beam to input beam: ≤ 6 arc min
Maximum error due to tolerances in polarizing optical elements: ± 30 nm (1.2 µin)
Thermal drift coefficient (change of indicated distance per degree C temperature change) (typical): < 0.04 micrometer/degree C (< 1.6 microinch/degree C)

Optical Signal Efficiency:
60% with a plane mirror having 99% reflectance at 633 nm at normal incidence.



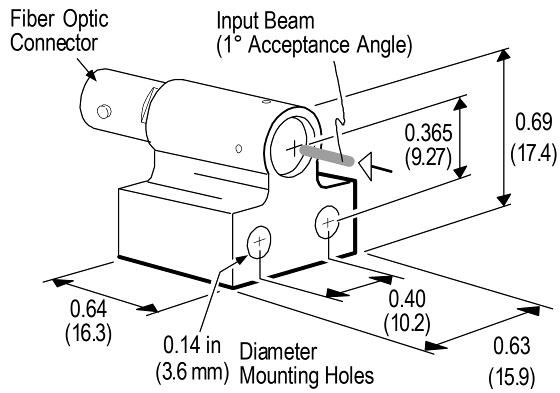
Dimensions shown in inches and (millimeters).

Fiber Optic Pickup   P/N 8040-0107-01

Dimensions: See Figure.
Weight: 4 g (0.2 oz)
Materials: Thermocomp RC-1004 and Ryton R-4
Typical Translation Range: ±1 mm
Mounting Surfaces (front face):
Flatness: 0.001 in. (0.025 mm)
Perpendicular and parallel to optical axis: 0.001 in. (0.025 mm)
Efficiency: ≥ 84%

Environmental:
Operating Temperature: 0 to 50° C (32 to 122° F)
Non-operating Temperature: -40 to 75° C (-40 to 167° F)
Operating Humidity: 0 to 90% (non-condensing)
Non-operating Humidity: 0 to 90% (non-condensing)

Specification Definitions
Acceptance Angle - angle range where relative efficiency is greater than 0.5.
Translation Range - lateral range across input beam where relative efficiency is greater than 0.5.

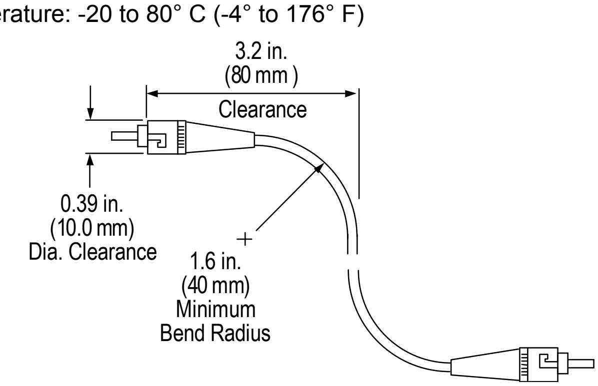


Dimensions shown in inches and (millimeters).

Fiber Optic Cable P/N 8020-0410-XX

Size: 400 micrometer core,
3.0 millimeter outside cable diameter.
Connectors: Male ST bayonet at both ends.
Cable Mechanical Specifications:
Maximum Tensile Load:
125 lb (500 N) short term
68 lb (300 N) long term
Crush Resistance: 428 lbs/in (750 N/cm)
Connector Pull Out Strength: 25 lb (225 N)
Environmental:
Operating Temperature: 0° to 70° C (32° to 158° F)
Non-operating Temperature: -20 to 80° C (-4° to 176° F)

XX	Length	Tolerance
01	1 meters	-0%, +5%
02	3 meters	-0%, +5%
03	5 meters	±0.5%
04	10 meters	±0.5%
05	0.6 meters	-0%, +5%
06	20 meters	±0.5%
07	15 meters	±0.5%



Mirror & Beamsplitter Mount P/N 6191-0445-01

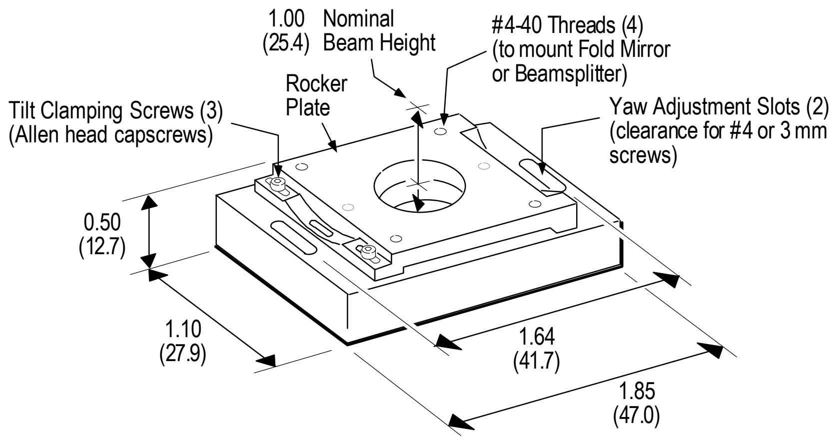
Description: Used to mount optical components with 1-inch square cells.

Dimensions: See Figure.

Weight: 86 grams (3.0 oz)

Materials: Magnetic Stainless Steel

Angular Adjustment:
Yaw: ± 8 degrees
Tilt: ± 4 degrees (when used with 3 clamping screws)
± 8 degrees (when used with 2 clamping screws in center slots of Rocker Plate)



Dimensions shown in inches and (millimeters).

Interferometer Mount P/N 6191-0446-01

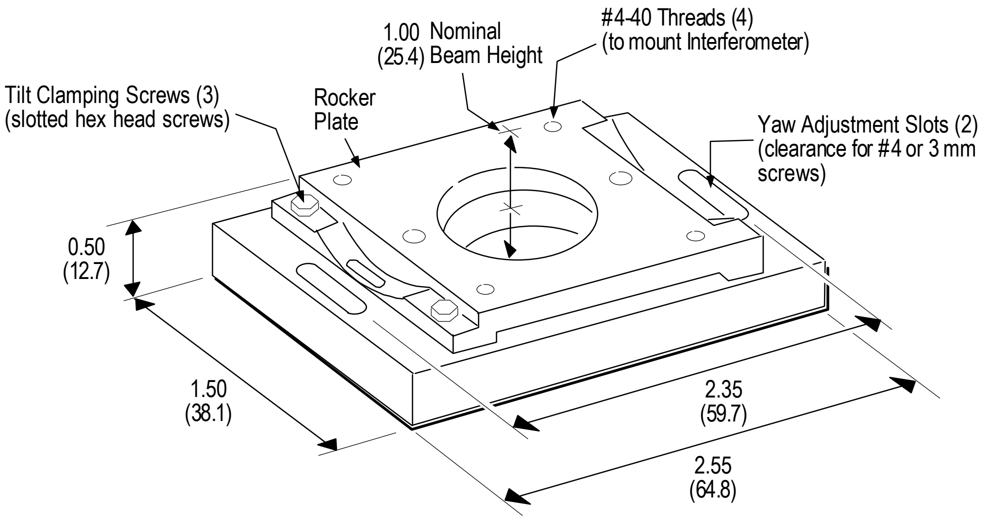
Description: Used to mount optical components with 1-1/2 inch cells.

Dimensions: See Figure.

Weight: 137 grams (5.0 oz)

Materials: Magnetic Stainless Steel

Angular Adjustment:
Yaw: ± 8 degrees
Tilt: ± 5 degrees

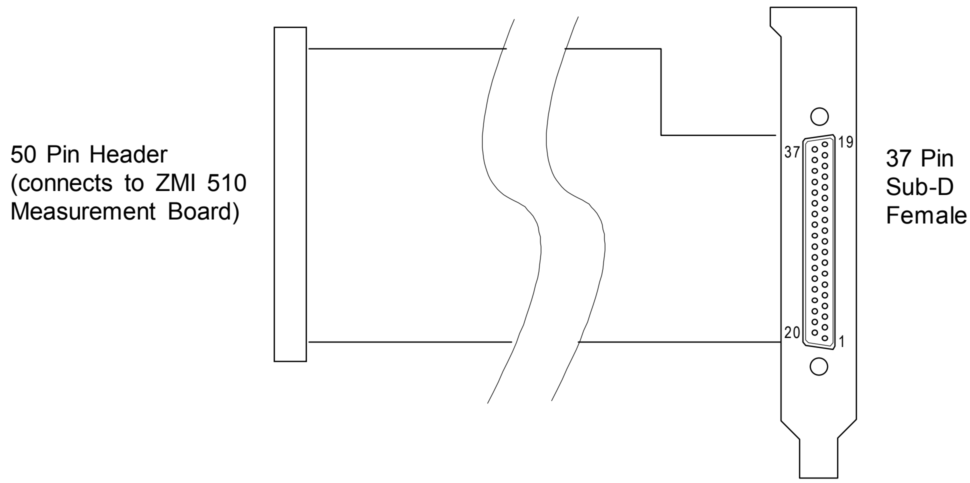


Dimensions shown in inches and (millimeters).

510 Data Cable   CS1115-801-369

Description:

This optional cable is used for interfacing the ZMI 510 Measurement Board to external controllers through a DB37 female connector.



50 Pin Header	Signal	37 Pin Sub-D Female
1	RESET IN	1
2	RESET IN*	20
3	SPARE	2
4	SPARE	21
5	CH1 ERR	3
6	CH1 ERR*	22
7	GND	4
8	CH2 ERR	23
9	CH2 ERR*	5
10	GND	24
11	CH3 ERR	6
12	CH3 ERR*	25
13	GND	7
14	CH1 A	26
15	CH1 A*	8
16	GND	27
17	CH1 B	9
18	CH1 B*	28
19	GND	10
20	CH2 A	29
21	CH2 A*	11
22	GND	30
23	CH2 B	12
24	CH2 B*	31
25	GND	13
26	CH3 A	32
27	CH3 A*	14
28	GND	33
29	CH3 B	15
30	CH3 B*	34
31	GND	16
32	MEAS ERR	35
33	MEAS ERR*	17
34	GND	36
35	TTL BIAS	18
36	GND	37
37	GND	19
38-50	N/C	

Laser Head Power Supply P/N 8010-0104-XX

Description:
Universal switching power supply provides ± 15 VDC for the ZMI laser heads (models 7702 and 7705). Available as an accessory.
For ZMI 2000 systems, use with ZMI Laser Head Cable P/N 1115-801-346 (not included). For ZMI 500 series systems, a user-made cable is required.

Part Numbers:

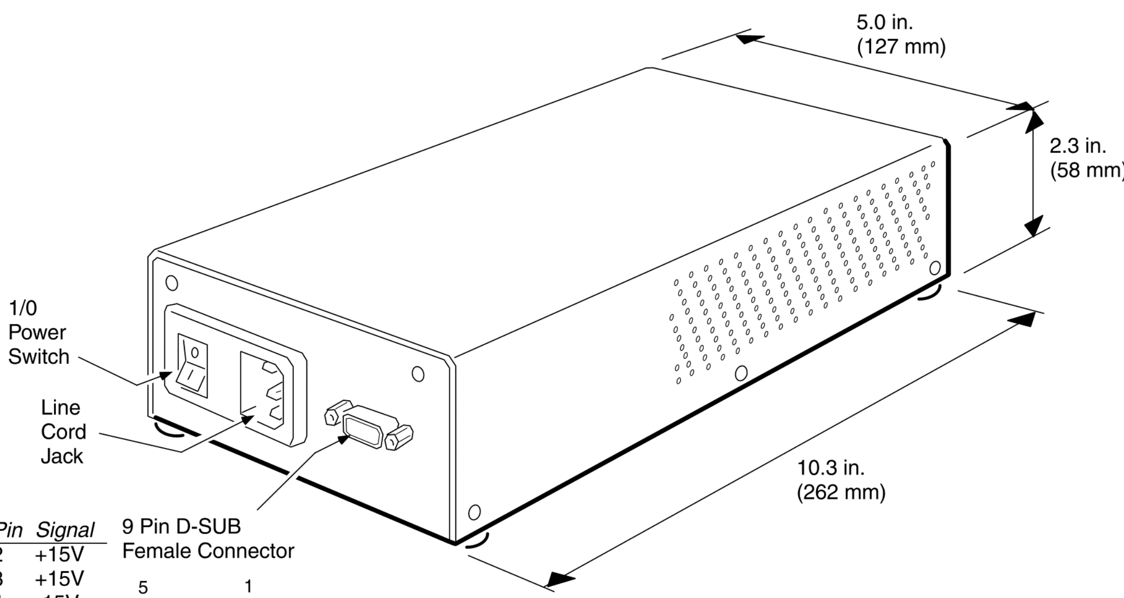
8010-0104-01	Domestic 110V
8010-0104-02	German/French 220V
8010-0104-03	Japan 100V
8010-0104-04	United Kingdom 240V

Physical Characteristics:
Dimensions: See Figure
Weight: 40.2 oz (1.1 kg)
Cable Clearance: 5 in. (127 mm)

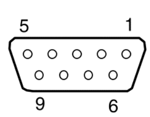
Mounting:
Self adhesive feet included, or may be attached with 4 screws (not included) into the threaded holes in the base.
Note: Provide clearance for air flow. Do not mount near measurement axes due to heat dissipation.

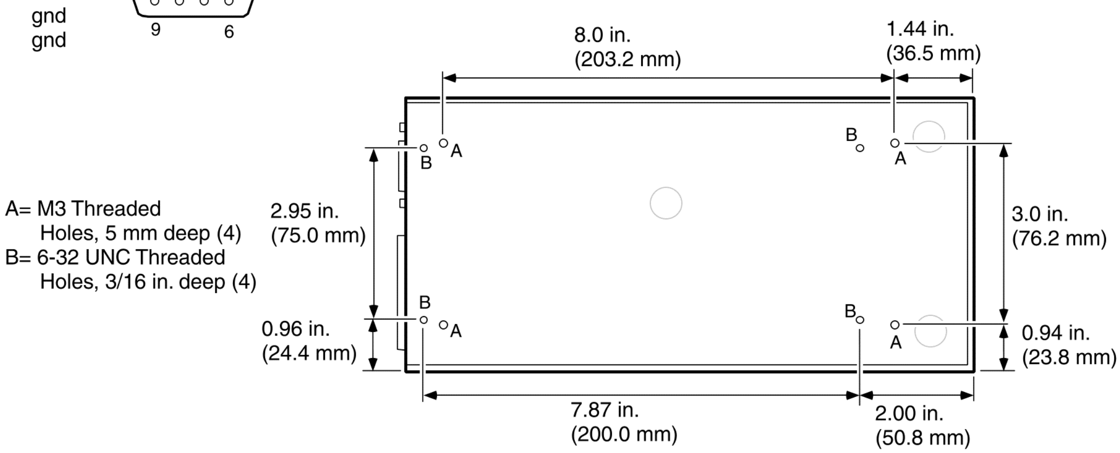
Electrical:
Input (nominal): 100 to 240 VAC, 50/60 Hz
Output: +15 VDC @ 2.5 A, -15VDC @ 2.0 A
Heat Dissipation: 12.8 watts maximum
Fuse Rating (power module): 250V 2A

Environmental:
Operating Temperature: 0 to 40°C
Operating Humidity: 0 to 85% (non-condensing)



Pin	*Signal*
2	+15V
3	+15V
4	-15V
5	-15V
6	gnd
7	gnd





Safety

Failure to follow the safety recommendations in this manual could result in damage to the system and may void the warranty.

Laser Safety

Before operating the Laser Head, please read the following material to become familiar with safety controls, markings, and warnings.

The Laser Head emits visible red light. The external radiant intensity output by the Laser Head is low; however, the intensity inside the Laser Head is greater. The external and internal radiation cannot burn or drill holes, even if a lens is used to focus the light. However, the laser light emitted by the laser should be treated with caution. It will not damage skin, but to protect your eyes, do not look directly into the laser beam or stare at its bright reflections.

Laser Safety Standards

The American National Standard for the Safe Use of Lasers (ANSI Z136.1-1986) classifies this laser product as Low Power - Class II (per Table A1), and provides reasonable and adequate guidelines for its safe use. The user and personnel responsible for the safe use of the Laser Head in the user's organization should consult this ANSI standard, available from:

American National Standards Institute
1430 Broadway
New York, New York 10018
Internet: http://www.ansi.org

The Laser Head conforms to the National Center for Devices and Radiological Health (NCDRH) of the Food and Drug Administration and to international laser safety regulations.

Product Use Warning

Warning!
Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

Output Beam Data

Laser Medium: Helium-Neon

Emission Duration: more than 0.25 second

Radiant Power: <1 milliwatt

Wavelength: 632.9 nanometers

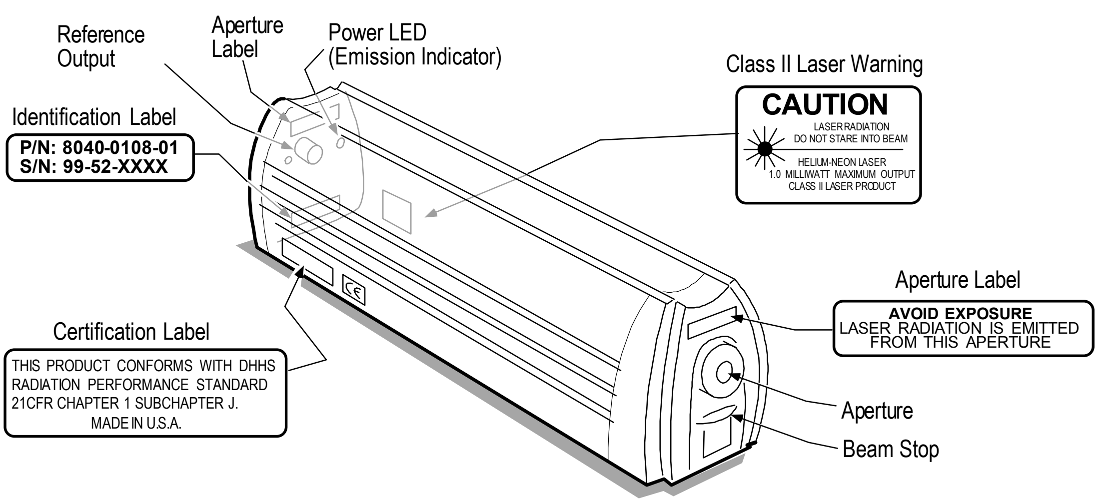
Laser Emission Control Devices

Device	*Function*
Rear Panel Power LED (Green)	When lit, indicates that power is being supplied to the laser, and that Class II laser radiation may be emitted from the Laser Head's aperture and reference port.
Beam Stop	When placed in no-output position, the laser beam is blocked from being emitted from the front aperture of the Laser Head.

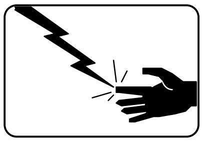
Laser Safety Labels

Label	*Purpose*
Class II Laser Warning	Federal requirement for Class II lasers.
Aperture	Labels the instrument's aperture through which laser radiation is emitted.
Certification	Shows that Zygo Corporation has conformed to the DHHS standard.
Identification	Provides the part number and serial for the laser.

Laser Head Safety Controls and Labels



Electrical Safety



Warning!

- **Ground the Instrument.** To minimize shock hazard, the equipment chassis and enclosure must be connected to an electrical ground. The ground wire on the chassis or enclosure must be reliably connected to an electrical ground at the power outlet. Ensure that the ZMI 501 Measurement Board and the Laser Head are properly grounded.
- **Use Proper ESD Handling Techniques.** Use proper ESD (electrostatic discharge) techniques when handling the board. The board should be stored in a static shield bag and handled only by individuals using a static control grounding devices. Avoid touching connectors on the board; electrostatic discharge can damage components.
- **Disconnect Power During Installation.** Do not install the board with power on. Install the board and connect cables only when power is off and the power cable is disconnected.
- **Do Not Modify Equipment.** Do not install substitute parts or perform any unauthorized modification of the board. Do not attempt to service or repair the Laser Head; voltages up to 2,000 volts may be present on the anode of the laser tube.

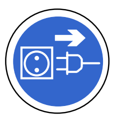
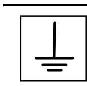
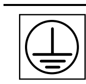
General Precautions

Warning!

- Handle optics with care; do not touch any glass surfaces.
- Do not clean optical surfaces unless necessary. Improper and unnecessary cleaning may damage optical coatings.
- User-supplied Laser Head mounting screws extending into the Laser Head deeper than 5/16-inch (8 mm) may damage the Laser Head.
- There are no user-serviceable parts in the ZMI 500 system; contact your Zygo representative.

Safety Labels

The following table describes the general meaning of safety labels found on the equipment. Specific warnings are covered in the applicable section within this manual. Failure to follow the safety labels and the recommendations in this manual could result in damage to personnel and the instrument, and may void the warranty.

Label	*Meaning*
	General hazard. Proceed with caution. Refer to the manual for instructions.
	Electrical shock hazard. Proceed with caution, there is a risk of electrical shock.
	Laser hazard. Avoid exposure to beam.
	Disconnect power.
	Refer to the manual for instructions.
	Earth ground.
	Protective conductor terminal.

Installation

Chapter 2

In This Chapter

- CE Note Regarding the Power Supply
- Installation Checklist
- Installing the ZMI 510 Measurement Board
    - Selecting System Resolution and Data Rate
- Connecting Cables
- Mounting the Laser Head
- Mounting Optical Components
- Optical Alignment
    - Basic Alignment Principles
    - Aligning Target Mirrors
    - Aligning the Output Laser Beam
    - Aligning the Beamsplitters and Fold Mirrors
    - Aligning the Straight-through HSPMI
    - Aligning the Right-angle HSPMI
    - Aligning the Fiber Optic Pickup
- Optimizing Alignment
    - ZMI 510 Measurement Board Test Point Characteristics

CE Note Regarding the Power Supply

The optional power supply is intended for Category 2 Installation per EN 61010-1, Clause 5.4.1, of the Low Voltage Directive of the European Union.

Installation Checklist

- [ ] Inspect all packages for signs of shipping damage. Report any damage to the carrier.
- [ ] Check that the shipment is complete.
- [ ] Set Measurement Board SW1, SW2, and SW3 DIP switches for the applicable selections; insert the board into the ISA backplane of the user-supplied PC computer. Connect a user-supplied cable to the output connector of Measurement Board.
- [ ] Mount the Laser Head. Connect the DB9 connector to a grounded +15 VDC power source. Connect a fiber optic cable between the Measurement Board "R" connector and the Laser Head reference connector.
- [ ] Using adjustable mounts, mount any HSPMI's, Beamsplitters, and Fold Mirrors in their applicable locations.
- [ ] Align the optical components starting with the Laser Head and working outward.
- [ ] Attach Fiber Optic Pickups to the HSPMI's. Connect a fiber optic cable to each pickup. Align each pickup.
- [ ] Connect fiber optic cables from the interferometers to the Measurement Board connectors.

Installing the ZMI 510 Measurement Board

1. Set switches SW1 (axis 1), SW2 (axis 2), and SW3 (axis 3) for the desired settings.

   Note: All switches on SW4 should be in the Off position.
2. Insert the Measurement Board into an open ISA slot in your computer.
3. Remove the plugs from the fiber optic connectors and connect the appropriate fiber optic cables from the Laser Head and the interferometer fiber optic pickups.
4. Connect the output connector to the applicable equipment with a user supplied cable.

DIP Switch Settings (Up=0=ON Down=1=OFF x=does not matter)
Set switches for SW1 (axis 1), SW2 (axis 2), and SW3 (axis 3)

Nominal(1) Data Rate (MHz)	*Nominal(1) Digital Filter Cutoff (kHz)*	*Resolution (nm)*	*Output Format*	*Polarity*	*Channel On/Off*
S1 S2 MHz	*S3 S4 S5 kHz*	*S6 S7 nm*	*S8*	*S9*	*S10*
0 0 14.60	x 0 0 97.4 (λ/64)	0 0 9.89	0 Quadrature	0 Normal	0 Enable
0 1 7.30	x 0 0 46.7 (λ/32)	0 1 19.78	1 Up/Down	1 Invert	1 Disable
1 0 3.65	x 0 0 23.0 (λ/16)	1 0 39.56			
1 1 1.83	x 0 0 11.3 (λ/8)	1 1 79.12			
	0 1 0 213.5				
	1 1 0 97.4				
	0 0 1 46.7				
	1 0 1 23.0				
	0 1 1 11.3				
	1 1 1 5.5				

(1) The "nominal" output data rate and –3dB cutoff frequency are based on the split frequency of the Laser Head; which is 3.65 MHz ± 10%. The maximum data rate is 4 times the split frequency.

Output Edge Connector Pinout (50-pin AMP 1-104315-9)

Quadrature

Pin	*Signal*	*Pin*	*Signal*
1	reset in	20	axis 2 A
2	reset in*	21	axis 2 A*
3	spare input	22	shield
4	spare input*	23	axis 2 B
5	axis 1 err	24	axis 2 B*
6	axis 1 err*	25	shield
7	shield	26	axis 3 A
8	axis 2 err	27	axis 3 A*
9	axis 2 err*	28	shield
10	shield	29	axis 3 B
11	axis 3 err	30	axis 3 B*
12	axis 3 err*	31	shield
13	shield	32	meas err
14	axis 1 A	33	meas err*
15	axis 1 A*	34	shield
16	shield	35	TTL bias
17	axis 1 B	36	gnd
18	axis 1 B*	37	gnd
19	shield	38	gnd
39 thru 50 not used			

Up/Down

Pin	*Signal*	*Pin*	*Signal*
1	reset in	20	axis 2 Up
2	reset in*	21	axis 2 Up*
3	spare input	22	shield
4	spare input*	23	axis 2 Down
5	axis 1 err	24	axis 2 Down*
6	axis 1 err*	25	shield
7	shield	26	axis 3 Up
8	axis 2 err	27	axis 3 Up*
9	axis 2 err*	28	shield
10	shield	29	axis 3 Down
11	axis 3 err	30	axis 3 Down*
12	axis 3 err*	31	shield
13	shield	32	meas err
14	axis 1 Up	33	meas err*
15	axis 1 Up*	34	shield
16	shield	35	TTL bias
17	axis 1 Down	36	gnd
18	axis 1 Down*	37	gnd
19	shield	38	gnd
39 thru 50 not used			

Selecting System Resolution and Data Rate

The ZMI 510 Measurement Board output is serial. The choice of resolution with switches 6 and 7, and the choice of data rate with switches 1 and 2, impacts the maximum velocity of the moving target that can be monitored. The finer the resolution and the slower the data rate, the lower the maximum velocity.

Resolution Versus Velocity

Nominal Resolution	*Nominal Data Rate (MHz)*	*Velocity Range (mm/sec)* (1) *Δf-10%*	*Δf*	*Δf+10%*
9.89 nm (λ/64)	14.60	129	144	158
	7.30	65	72	79
	3.65	32	36	40
	1.83	16	18	20
19.78 nm (λ/32)	14.60	260	289	317
	7.30	129	144	158
	3.65	65	72	79
	1.83	32	36	40
39.56 nm (λ/16)	14.60	500	500	500
	7.30	260	289	317
	3.65	129	144	158
	1.83	65	72	79
79.12 nm (λ/8)	14.60	500	500	500
	7.30	500	500	500
	3.65	260	289	317
	1.83	129	144	158

(1) Δf is equal to 3.65 MHz ± 0.35 MHz (10%). This frequency difference of the two Laser Head beam components limits the maximum velocity for a given resolution setting.

Nominal versus Maximum Data Rates

The ZMI 510 Measurement Board is a digital system emulating analog output. The output data rate should be exactly proportional to the slew rate of the axis of motion. However there can be small edge to edge variations in this output data rate. This may become problematic when the maximum output data rate exceeds the rating for the counter electronics interfaced on the P2.

The timing analysis is:

1.) Nominal Data Rate = DR_n = Frequency Split of Laser Head * 4

2.) Measurement Board Clock Rate = Clk = Frequency Split of Laser Head * 16

3.) Maximum clock resolution error = $E_r = \pm 4$ ns

4.) Max Data Rate = $DR_{max} = (1/DR_n - E_r)^{-1}$

Assuming a nominal split frequency of 3.65MHz:

DR_n = 3.65 MHz * 4 = 14.6 MHz = 68.49 ns (edge to edge)

Clk = 3.65 MHz * 16 = 58.40 MHz = 17.12 ns (edge to edge)

$DR_{max} = ((1/14.6 \text{ MHz}) - 4\text{ns})^{-1}$ = 15.51 MHz (~6% greater than DR_n)

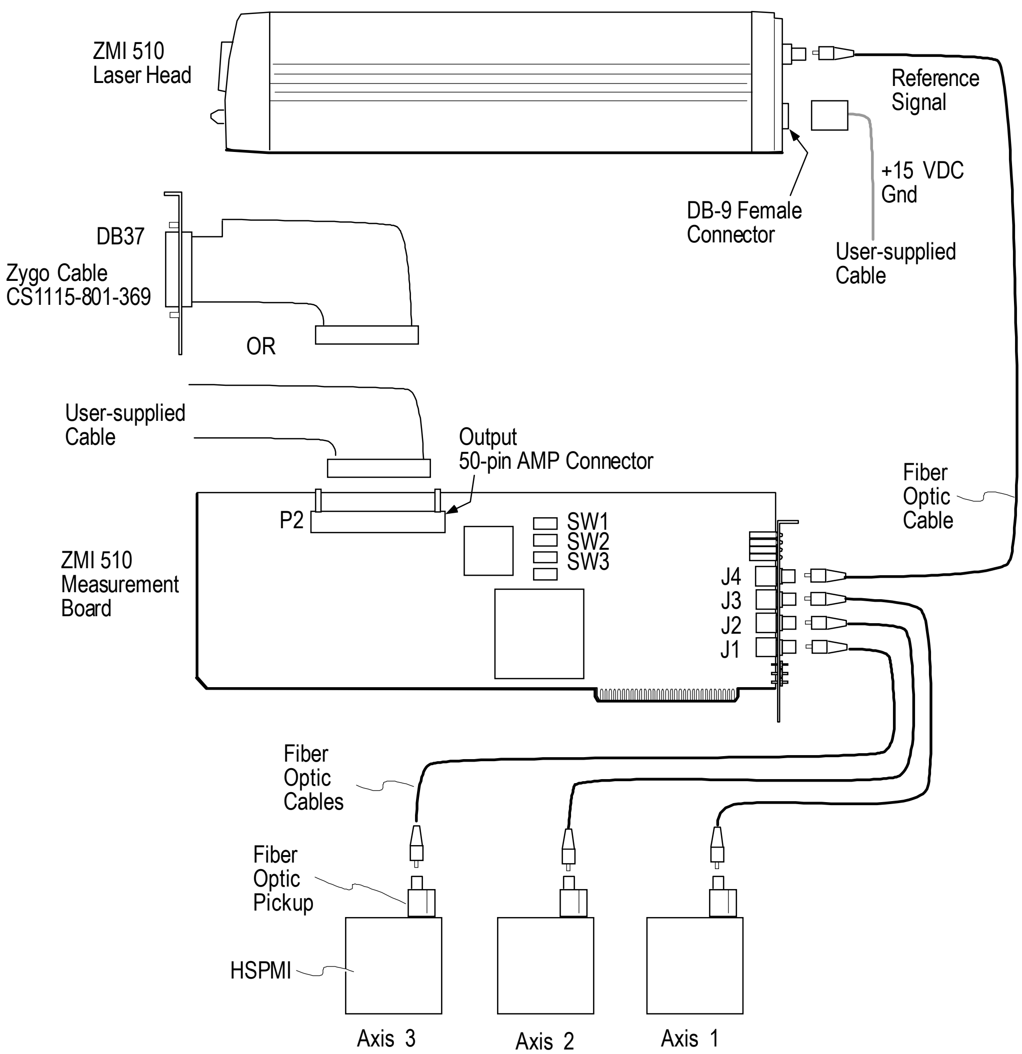
Manufacturing data for Zygo's laser heads, including the actual frequency split for any laser head is kept at Zygo. Please contact technical support, or use our website to ask for this number if it is determined that the Max Data Rate may be a problem.

Connecting Cables

Warning!

- Turn power off before connecting or disconnecting cables.
- Align keyed connectors before connecting; failure to align mating connectors may damage the pins or the connector.
- Ensure that the DB9 connector ground pins are connected to earth ground through the user-supplied laser cable.

Component Interconnection

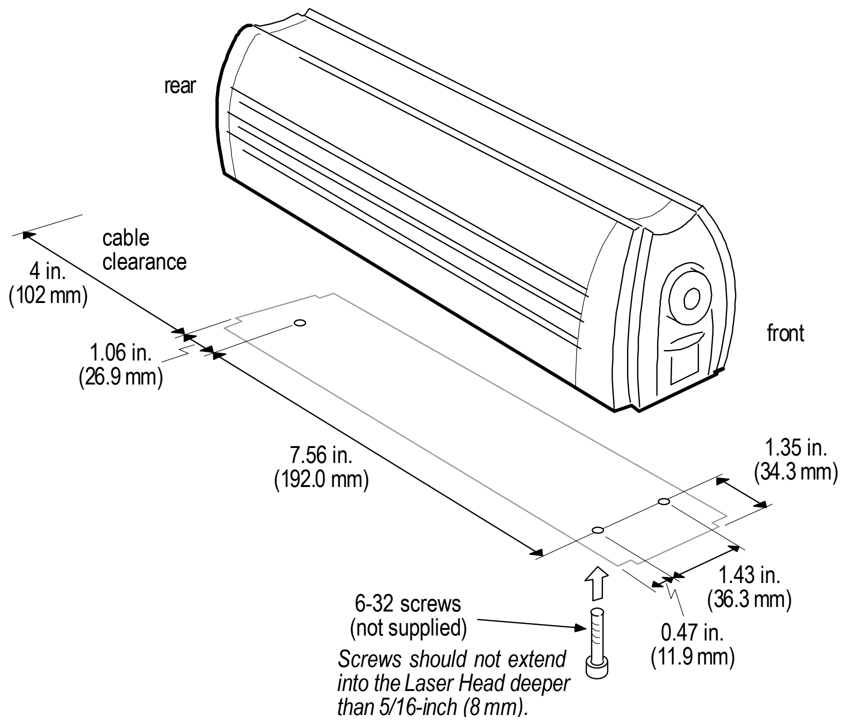


Mounting the Laser Head

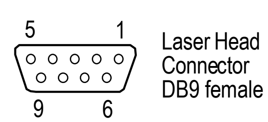
The following considerations must be addressed when mounting the Laser Head:

- The Laser Head must be positioned so its output beam is perpendicular or parallel to the machine measurement axes.
- The Laser Head output beam must be centered in the optical component's aperture.
- Allow at least 4 in. (102 mm) at the rear of the Laser Head for connector and cable clearance.
- The Laser Head is attached to the mounting surface with three 6-32 screws from the bottom. These screws must *not* extend further than 5/16-inch (8 mm) into the Laser Head. For other mounting options contact your Zygo representative.

Laser Head Mounting



Laser Head DB9 Connector Pinout



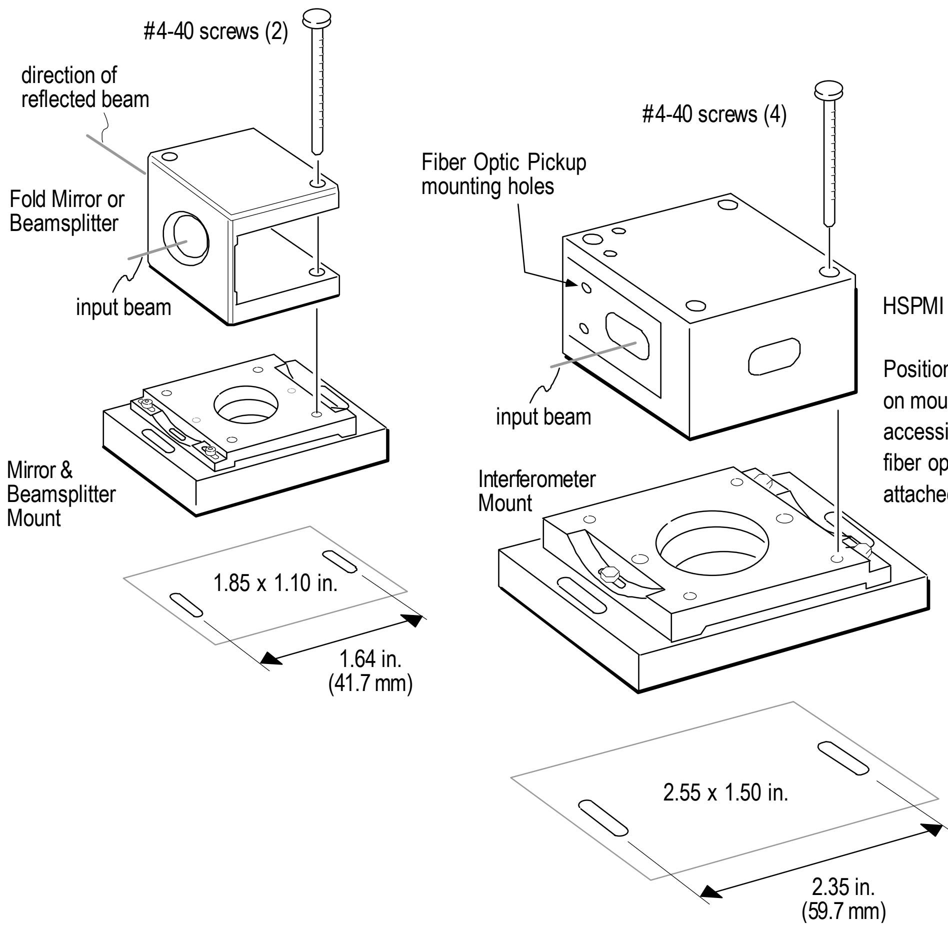
Pin	*Signal*
1	Locked_P (optional)
2	Locked*_P (optional)
3	signal gnd (optional)
4, 5, and 6	+15 VDC
7 and 8	gnd
9	shield gnd

Mounting Optical Components

The following considerations must be addressed when mounting the HSPMI, Fold Mirror, or Beamsplitters:

- The optical components must be mounted so that the sides are perpendicular or parallel to the plane defined by the Laser Head within ±1 degree.
- Locate optical components so they are not subject to thermal gradients or machine vibrations.
- Use Zygo mounts to attach the optical components to the mounting surface. These mounts allow for adjustment during alignment. The component should be oriented on the mount so the reflected beam rotates about the input laser beam. (The input beam parallel to the long axis of the mount.)

Mounting Optical Components



Optical Alignment

To achieve the maximum accuracy possible with an interferometer, all optical components must be properly aligned. Careful alignment minimizes the cosine error, which occurs when the measurement beams are not perpendicular to the stage's plane mirrors or to the axis of travel. The acceptable misalignment depends on the application. For example, a 0.1° misalignment cause a 1.5 ppm (parts-per-million) error, and a 1° misalignment causes a 152 ppm error. In other terms, a beam misalignment of one millimeter, at a distance of one meter from the interferometer, will contribute an error of approximately 0.5 ppm (0.5 µm).

Basic Alignment Principles

Alignment requires meticulous effort and repetition of steps. Optical alignment is best performed in a series of separate, consecutive "modular" procedures. These modular procedures are described in detail over the pages that follow. Perform the procedures required for your particular application. The recommended modular steps are:

1. Align the *target mirror(s)* parallel and/or perpendicular to the measurement axes of the application.
2. Align the laser output *beam* perpendicular to the target mirror(s). Ensure that the beam is aligned over the full range of travel.
3. Align all Fold Mirrors and Beamsplitters beginning with the components closest to the Laser Head, such that each reflection is 90°.
4. Align the interferometer(s), one measurement axis at a time, per the detailed procedures in this manual.
5. Align the Fiber Optic Pickup and verify the signal strength at the test point on the measurement board for each axis.

Alignment Considerations

- Alignment can begin as soon as the Laser Head is turned on and the "lock" LED has illuminated.
- Locate the component mounting positions so that only minor translations and rotations will be required to bring the optical components into proper alignment.
- To facilitate alignment, use adjustable mounts for all components.
- Firmly secure each component after it is aligned.
- Ensure that sufficient power is present at each Fiber Optic Pickup. Measure the test point voltage on each measurement board, as explained in the section "Optimizing Alignment" at the end of this chapter.

Aligning Target Mirrors

The first step in aligning any optical components is to accurately align the target mirror(s) (plane mirror or retroreflector) to the measurement axes. Careful design of your application to provide precision mounting of the target mirror can help expedite this procedure. Mechanical or electronic indicators are usually necessary for this procedure.

A retroreflector is used on a linear interferometer in an application that translates in only one direction. Multi-pass interferometer configurations require plane mirrors as the target. The clear aperture of the mirror is based on the translation range of the components.

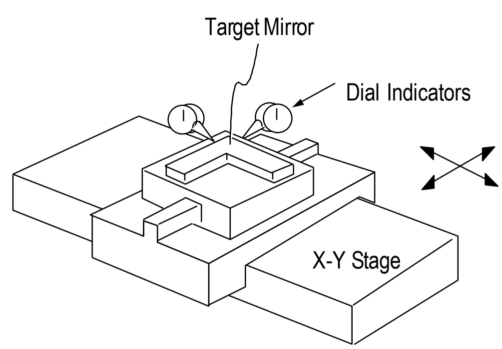
Target Mirror - Mechanical Alignment

1. Position the mirrors on the stage.

   ⚠ **Warning!** Be careful not to scratch the coated surface of the mirror when using the indicator in the following step.

2. Carefully position the dial indicator tip on the mirror surface outside the clear aperture, or on the back surface if it is parallel to the mirrored surface.
3. Translate the stage through its full range of travel. Adjust the rotation of each mirror to minimize the deviation measured by its indicator.
4. Secure the mirror and verify alignment.

Target Mirror Mechanical Alignment

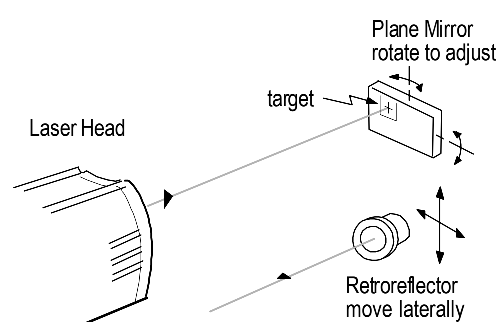


The face of the mirror should be parallel to the axis of motion of as measured by the dial indicator.

Target Mirror - Optical Alignment

1. Temporarily attach a paper target, with a hand drawn cross, on the mirror at the location of the laser beam.
2. Translate the stage over its full range of travel. If the beam walks off the target the mirror is not aligned to the axis of travel.
3. Adjust the mirror alignment until the beam remains on the target cross over the entire range of travel.

Target Mirror Optical Alignment



As the stage is translated over its full range of travel the beam should stay centered in the target. If necessary, adjust the mirror or retrorflector until this condition is met.

Aligning the Output Laser Beam

1. Mount the Laser Head and provide + 15 VDC power. Turn on the Laser Head and allow it to stabilize.

   Note: The beam pointing of the Laser Head can change up to 0.2 mrad from a cold startup to thermal equilibrium (approximately 1 hour). If the path length is greater than 13 feet (4 meters), it is recommended to let the Laser Head reach thermal equilibrium before doing final interferometer alignment.

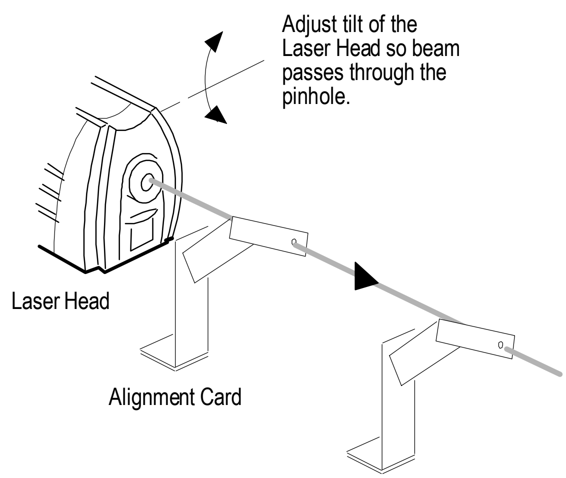
2. Place the Alignment Card in front of the Laser Head so the center of the beam goes through the center of the pinhole in the card.

3. To align the output beam parallel to the reference (mounting) surface:

   a. Move the Alignment Card along the reference surface. Adjust the tilt of the Laser Head so the beam goes through the center of the pinhole in the card. Ensure that the beam is centered in the Alignment Card pinhole as the card is moved along the full length of the reference surface.

   b. If necessary, adjust the height of the Laser Head so the beam is at the centerline height of the optical components.

Aligning Beam to Surface

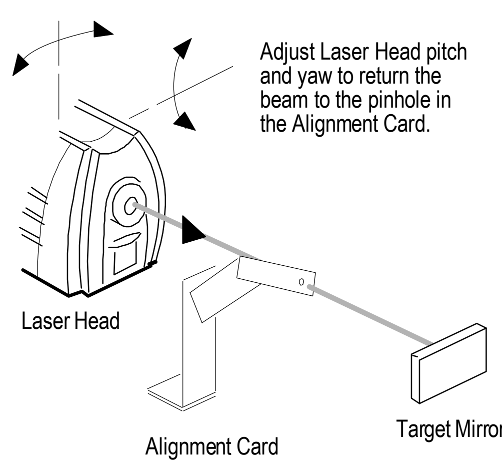


4. To align the output laser beam parallel to the axis of travel: (This step assumes that the target mirror is aligned to the axis of travel.)

   a. Adjust the horizontal rotation of the Laser Head so the beam goes through the center of the pinhole in the alignment card and reflects back from the target mirror to the center of the same hole. It should do this throughout the complete range of travel.

   Note: If the output beam of the laser is designed to be perpendicular to the axis of travel, place a penta prism in the beam path to establish the 90° bend.

Aligning Beam to Axis



Aligning Fold Mirrors and Beamsplitters

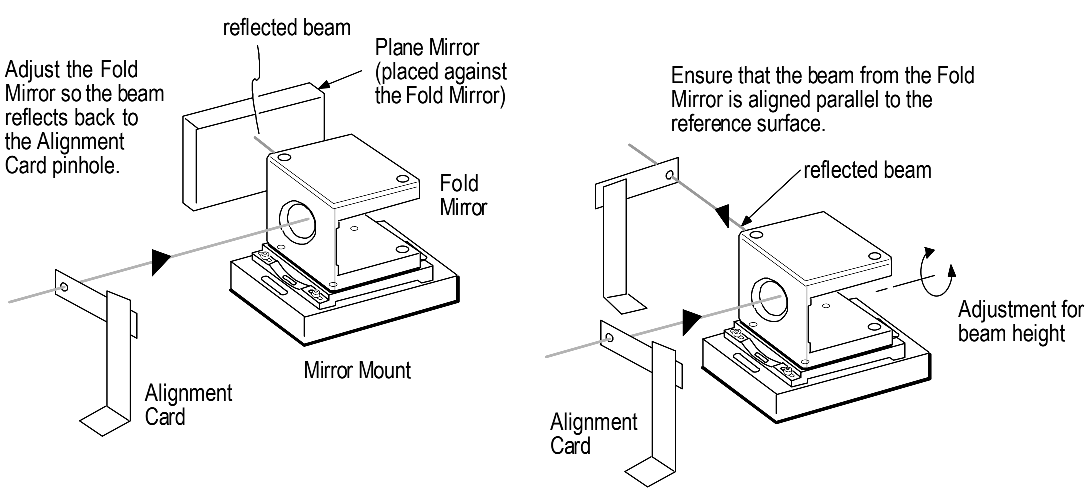
Required Alignment Aids: Alignment Card and Plane Parallel Mirror

All Fold Mirror and Beamsplitters used in the measurement system must be aligned parallel or perpendicular to the laser beam. Precise alignment of beamsteering optics in an interferometer system requires highly stable, adjustable mounts, such as the Zygo Beamsplitter & Mirror Mount.

> **Note:** Begin the alignment with the optical component nearest to the Laser Head and work outward.

1. Turn on the Laser Head and allow it to stabilize. Place the Alignment Card in front of the Laser Head so the center of the beam goes through the center of the pinhole in the card.
2. To align a *Fold Mirror:*
   a. Attach the Fold Mirror to the Mount. Position the mirror on the mount so that the reflected beam rotates about the input laser beam, and that the beam is centered in its input aperture.
   b. Place a Plane Parallel Mirror against the output face of the Fold Mirror. The mirror reflects the beam back through the Fold Mirror and toward the Laser Head. Adjust the tilt of the Fold Mirror so the beam reflects back through the center of the Alignment Card pinhole.
   c. Ensure that the reflected beam from the Fold Mirror is aligned parallel to the reference (mounting) surface. Place the alignment flag in the beam path before the mirror. Position the flag at the furthest location from the mirror in the reflected beam path. Adjust the tilt of the mirror until the reflected beam passes through the same hole in the flag.

Aligning a Fold Mirror



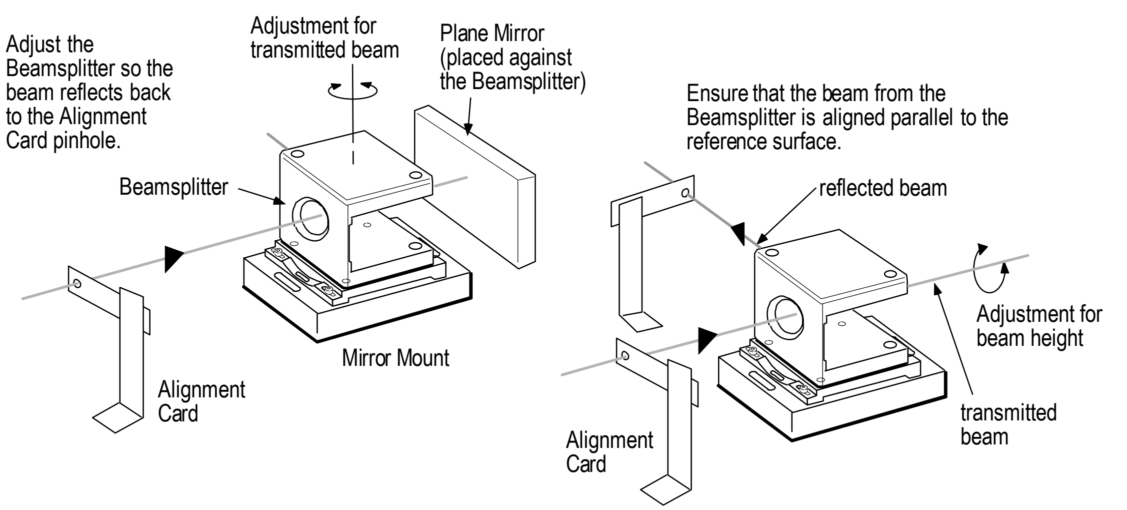
3. To align a *Beamsplitter*:

   a. Attach the Beamsplitter to the Mount. Position the Beamsplitter on the mount so that the reflected beam rotates about the input laser beam, and that the beam is centered in its input aperture.

   b. Place a Plane Parallel Mirror against the output transmitted face of the Beamsplitter. The Alignment Mirror reflects the beam back through the Beamsplitter to the Laser Head. Adjust the tilt of the Beamsplitter so the transmitted beam reflects back to the center of the Alignment Card pinhole.

   c. Ensure that the reflected beam from the Beamsplitter is aligned parallel to the reference (mounting) surface. Place the alignment flag in the beam path before the Beamsplitter. Position the flag at the furthest location from the Beamsplitter in the reflected beam path. Adjust the tilt of the Beamsplitter until the reflected beam passes through the same hole in the flag.

Aligning a Beamsplitter



Aligning the Straight-through HSPMI

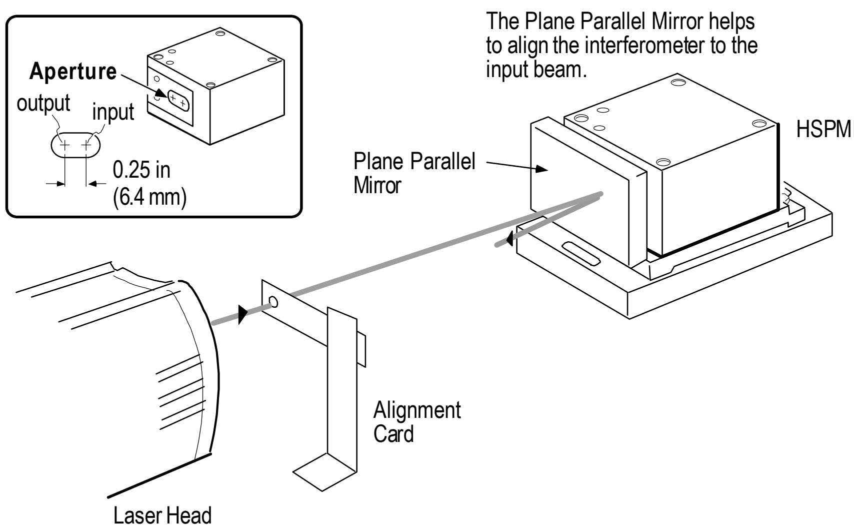
Required Alignment Aids: Alignment Card, Plane Parallel Mirror, and Alignment Target

1. Turn on the Laser Head and allow it to stabilize. Place the Alignment Card in front of the Laser Head so the beam goes through the center of the pinhole in the card.

2. Attach the interferometer on its mount. . The mount must be oriented so the rocker plate rotates about the input beam. Adjust the position of the mount so the input beam is centered in the input aperture of the interferometer. Depending on the location of the interferometer, the input beam may overfill the aperture and show a uniform thin annulus around the aperture.

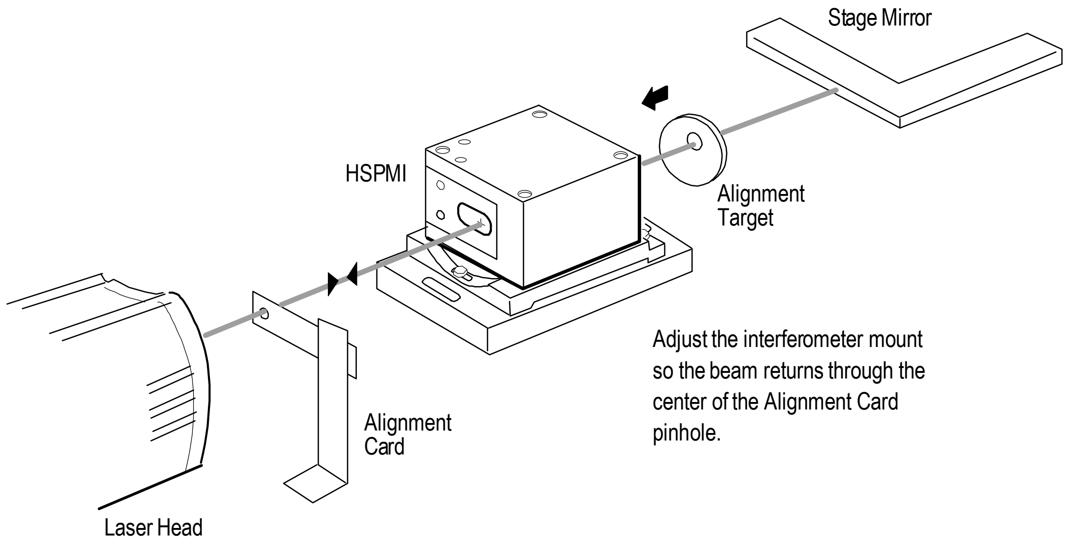
3. Align the interferometer to the input beam:
   a. Place a Plane Parallel Mirror against the front surface of the interferometer. Adjust the tilt of the interferometer so the beam reflected from the mirror returns to the center of the Alignment Card pinhole. Then remove the mirror.
   b. Check that the beam is still centered in the interferometer's input aperture. If necessary, adjust the interferometer's position.

Straight-through HSPMI Alignment



4. Align the interferometer's measurement beam to the target mirror:
   a. Place an Alignment Target (with integral quarter waveplate) in the output beam of the interferometer. The beam should reflect back from the target mirror to the interferometer and to the Alignment Card placed in front of the Laser Head.
   b. Adjust the mount until the reflected beam is centered in the Alignment Card pinhole.
   c. Make sure that the input beam is centered in the interferometer's aperture; if necessary, adjust the interferometer's position.
   d. Remove the Alignment Target and view the beams on the target mirror. Two beams, horizontally separated by 0.25 in (6.4 mm), should be present.
5. Check the interferometer alignment:
   a. At the output beam location check for overlap of the reference and measurement beams by blocking and unblocking the measurement beam between the interferometer and the target mirror.
   b. Fine adjust the alignment of the interferometer to optimize the beam overlap.
   c. Mount and align the Fiber Optic Pickup as explained later in this chapter.

Straight-through HSPMI Measurement Beam Alignment



Aligning the Right-Angle HSPMI

Required Alignment Aids: Alignment Card, Plane Parallel Mirror, Alignment Target; Penta Prism (optional)

1. Turn on the Laser Head and allow it to stabilize. Place the Alignment Card in front of the Laser Head so the beam goes through the center of the pinhole in the card.
2. *With Penta Prism* To adjust the input beam perpendicular to the axis of travel:

   Note: If a penta prism is not available, skip to the next step. (A penta prism establishes a perpendicular relationship between the input beam and the reflected beam.)

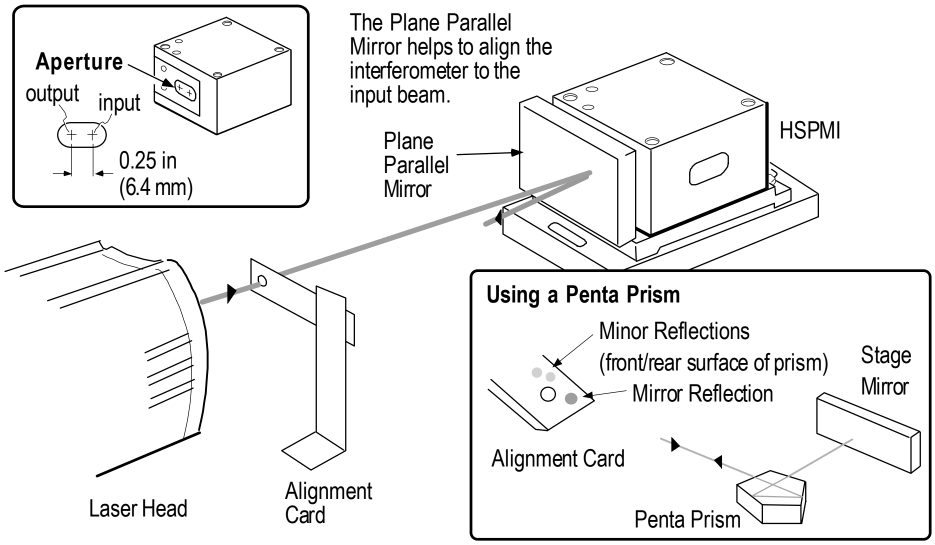
   a. Place a penta prism in the position where the interferometer will be mounted. Adjust the tilt of the penta prism so the front surface reflection is horizontally centered in the Alignment Card pinhole.

   b. Adjust the laser head so the target mirror reflection is horizontally centered in the Alignment Card pinhole.

   c. Remove the penta prism and install the interferometer on its mount. The mount must be oriented so the rocker plate rotates about the input beam. Adjust the position of the mount so the input beam is centered in the input aperture of the interferometer. The input beam may overfill the aperture and show a uniform thin annulus around the aperture.

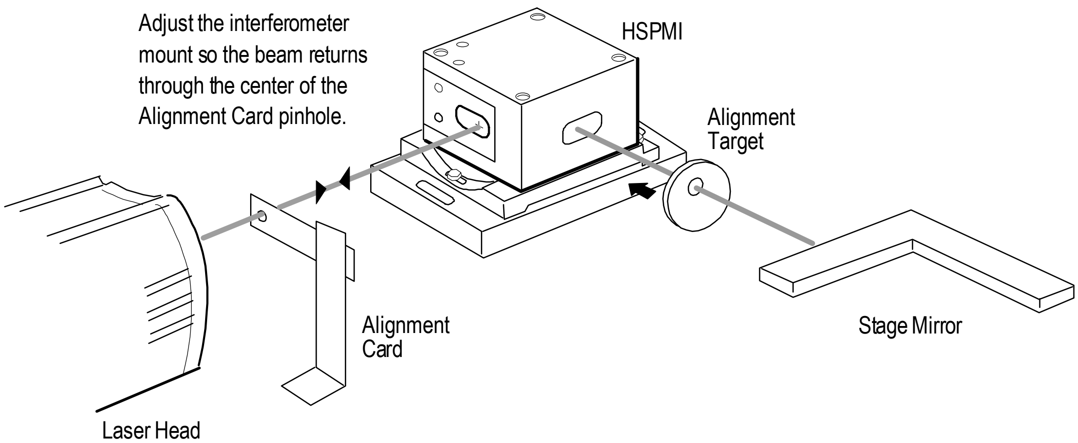
   d. Go to Step 4.

Right-angle HSPMI Alignment



3. *Without Penta Prism* To adjust the interferometer perpendicular to the axis of travel:
   a. Attach the interferometer on its mount. Adjust the position of the interferometer so the input beam is centered in the input aperture of the interferometer.
   b. Place a Plane Parallel Mirror against the front surface of the interferometer. Adjust the tilt of the interferometer so the beam reflected from the mirror is centered in the Alignment Card pinhole.
   c. Repeat the above steps until both the above conditions are met.
4. Align the interferometer's measurement beam so that it is perpendicular to the target mirror:
   a. Place an Alignment Target (with integral quarter waveplate) in the output beam of the interferometer. The beam should reflect back from the target mirror to the interferometer and through the center of the hole in the Alignment Card placed in front of the Laser Head.
   b. Adjust the mount until the reflected beam is centered in the Alignment Card pinhole.
   c. Check that the input beam is still centered in the interferometer's aperture. If necessary, adjust the interferometer's position.
   d. Remove the Alignment Target and view the beams on the target mirror. Two beams, horizontally separated by 0.25 in (6.4 mm), should be present.
5. Check the interferometer alignment:
   a. At the output beam location check for overlap of the reference and measurement beams by blocking and unblocking the measurement beam between the interferometer and the target mirror.
   b. Fine adjust the alignment of the interferometer to optimize the beam overlap.
   c. Mount and align the Fiber Optic Pickup as explained later in this chapter.

Right-angle HSPMI Measurement Beam Alignment

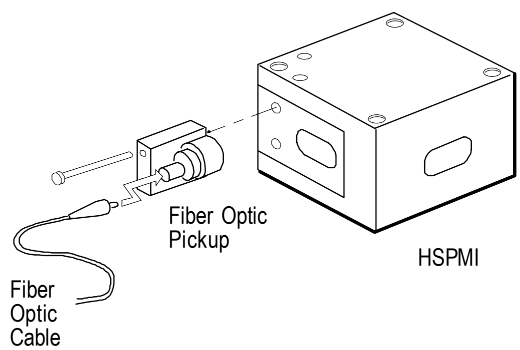


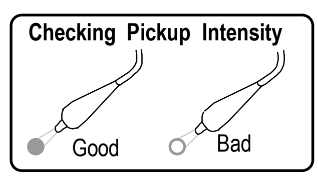
Aligning the Fiber Optic Pickup

Note: Align the interferometer before aligning the Fiber Optic Pickup.

1. Mount the Fiber Optic Pickup to the interferometer. Leave the screws slightly loose so the pickup can be translated.
2. Translate the Pickup until the output beam is centered in the Fiber Optic Pickup lens.
3. Remove the protective covers from both ends of the fiber optic cable. Attach one end of the cable to the pickup.
4. Direct the beam from the end of the cable onto a piece of white paper and check the light intensity pattern. The pattern should be a uniform red circle. If the pattern is ring or donut shaped, adjust the tilt of the Pickup or the interferometer to optimize the signal.
5. Tighten the screws securing the Fiber Optic Pickup.
6. Continue with “Optimizing Alignment”.

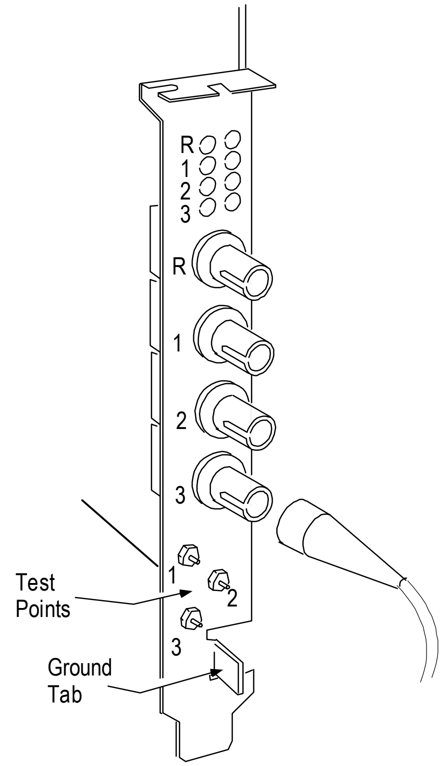
Fiber Optic Pickup Alignment





Optimizing Alignment

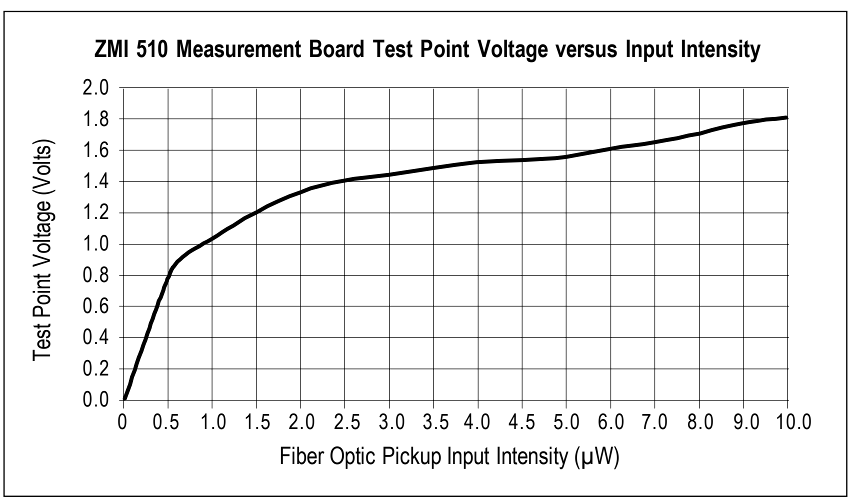
After the interferometer system is installed and aligned, each axis should be optimized for maximum signal. Test points for each axis, located on the connector panel of the ZMI Measurement Board, provide a direct reading of the signal strength at the board's detector. For typical test point voltages see "ZMI 510 Measurement Board Test Point Characteristics".



1. Connect the fiber optic cable to the Measurement Board.
2. Connect the positive lead from a voltmeter to the Test Point on the Measurement Board, and connect the negative lead to ground on the tab on the connector.
3. Carefully adjust the alignment of the interferometer to obtain the maximum voltage reading. Disconnect the voltmeter when complete.

ZMI 510 Measurement Board Test Point Characteristics

The Input Intensity refers to the intensity at the end of the fiber optic cable going into the Measurement Board. The graph shows a typical transfer function characteristic; with a tolerance of about 20% due to Measurement Board component tolerances. In general, the interferometer alignment for each axis should be adjusted to maximize the test point voltage.



Operation

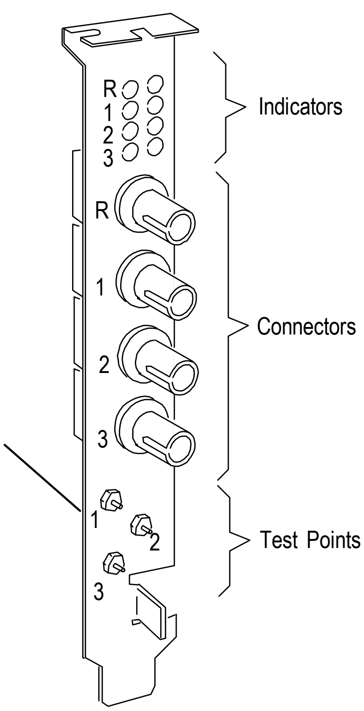
Chapter 3

In This Chapter

- ZMI 510 Measurement Board
  - Measurement Board Connector Panel
  - Meaning of Measurement Board Indicators
  - Error Reporting
  - Digital Filtering
  - Digital Filter Details
- Laser Head Operation
  - Laser Head Back Panel
  - The Laser Head Locked Signal
- Getting Started
  - Initialization
  - Dealing With Errors
- Theory of Operation

ZMI 510 Measurement Board

Measurement Board Connector Panel



Component	*Description*
Indicators	Green signal present LED and amber error LED for Laser Head Reference signal (R), axis 1 measurement signal (1), axis 2 measurement signal (2), and axis 3 measurement signal (3).
Connectors	Fiber Optic connectors for Laser Head Reference cable (R), axis 1 measurement cable (1), axis 2 measurement cable (2), and axis 3 measurement cable (3).
Test Points	Test points for checking optical alignment for axis 1 (1), axis 2 (2), and axis 3 (3).

Meaning of Measurement Board Indicators

Indicator(s)	*LED Color*	*Description*
R 1 2 3	Green	When On the applicable signal is present.
R	Amber	When On the Measurement Board is not receiving a valid Laser Head reference signal.
1 2 3	Amber	When On a number of problems may have occurred with the applicable measurement signal: the signal is missing, the signal dropped below the acceptable level, the moving target exceeded maximum velocity, the moving target exceeded maximum acceleration, or the position data overflowed.

Error Reporting

All error conditions (amber LEDs) listed in the above table are logically "ORed" and latched to generate the error signal for the user's servo controller. All error signals are active high. When an error occurs all output data is inhibited; all errors are considered fatal. Latched error signals are cleared by a reset signal from the servo controller.

Digital Filtering

Digital filtering is used to eliminate noise from the measurement signal. Noise is usually caused by environmental conditions, such as vibrations and air turbulence. Filtering for the ZMI 510 is always active; it provides a zero-time-delay [(1)] , 2nd order low-pass digital filter to eliminate the high frequency components in the measurement signal.

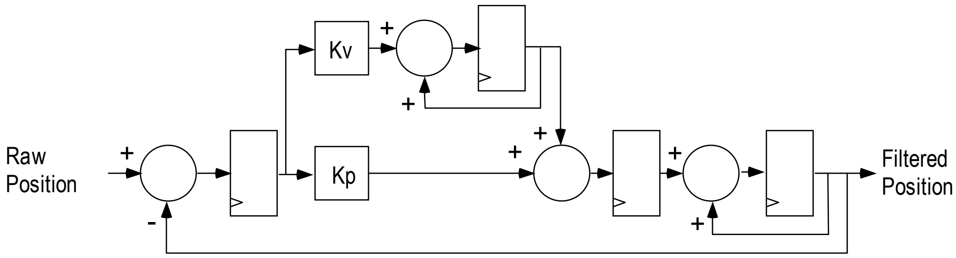
The 2nd order low-pass digital filter smoothes the raw displacement values. The output converter generates quadrature from the low order bits of the digital filter output. The quadrature is output at a rate proportional to the velocity of the target, with a worst case accumulated error of less than 1 count of the "true" stage position. The converter outputs an error condition if the data changes at a rate faster than the user selected output rate. This prevents the measurement board from accumulating counts. Zygo recommends that users set the cutoff frequency at least 10 times the open loop stage bandwidth to prevent interaction between the control loop and the digital filter.

Each measurement axis has independent control switches. These switches are marked on the board as SW1, SW2, and SW3 corresponding to axes 1, 2 and 3, respectively. Switch positions 3, 4, and 5 control the digital filter gain setting and therefore the –3dB cutoff frequency of the filter.

(1) The zero-time-delay is constrained by the nominal data rate. To find the actual time delay of the digital filter take the reciprocal of the data rate.

The digital filter block diagram is shown below. The filter position transfer function is also provided.

Digital Filter Block Diagram



Position Transfer Function of the Digital Filter

$z(f) = e^{-j2\pi fTc}$
Tc = 14.6MHz
$Xp = 2^{Kp}$
$Xv = 2^{Kv}$

$$\frac{POut}{PIn} = \left[\left(X_p - X_v\right)\cdot z(f) - X_p\right]\cdot\frac{z(f)^3}{\left[\left(X_p - X_v\right)\cdot z(f)^4 - z(f)^3\cdot X_p - z(f)^2 + 2\cdot z(f) - 1\right]}$$

Using the factory default digital filter setting of 4 = on and 5 = on, the digital filter cutoff frequency is a function of the resolution selected by switch positions 6 and 7. The cutoff frequency is independent of the resolution selection for all other filter settings. This is summarized in the following table.

Relationship Between Switch Settings, Digital Filtering, and Resolution

SW Position 3	*SW Position 4*	*SW Position 5*	*SW Position 6*	*SW Position 7*	*Kp*	*Kv*	*Cutoff Frequency*	*Resolution*
X	on	on	on	on	-5	-12	97.4 kHz	λ/64
X	on	on	on	off	-6	-14	46.7 kHz	λ/32
X	on	on	off	on	-7	-16	23.0 kHz	λ/16
X	on	on	off	off	-8	-18	11.3 kHz	λ/8
on	off	on	X	X	-4	-10	213.5 kHz	X
off	off	on	X	X	-5	-12	97.4 kHz	X
on	on	off	X	X	-6	-14	46.7 kHz	X
off	on	off	X	X	-7	-16	23.0 kHz	X
on	off	off	X	X	-8	-18	11.3 kHz	X
off	off	off	X	X	-9	-20	5.5 kHz	X

Notes: X = don’t care, setting does not effect digital filter cutoff frequency.
The –3db cutoff frequency is based upon a nominal laser reference frequency of 3.65 MHz.

Why does the ZMI 510 use a digital filter?

All systems have noise. Noise sources include:

- Laser amplitude noise from the laser head (negligible in the ZMI 510 Laser Head)
- Photodiode shot noise (negligible in the ZMI 510 Measurement Board)
- Fiber optic receiver preamp input short circuit noise and Johnson noise in the feedback resistor (negligible in the ZMI 510 Measurement Board)
- Quantization noise from the phase meter
- General circuit noise from power supplies, signal crosstalk, EMI, etc.
- System noise such as vibration, air turbulence, motor force ripple, etc.

A filter is needed in all systems to reduce or eliminate noise outside the signal bandwidth of interest. Zygo uses digital filters because analog filters have problems with component tolerances, linearity, signal crosstalk, power supply sensitivity, thermal sensitivity, EMI sensitivity, etc. In addition, the digital filter provides a constant output data rate.

What is the effect of the different digital filter settings in the ZMI 510?

The ZMI 510 provides users with the ability to select the digital filter bandwidth. For example, the open loop bandwidth of most stage systems is below 500 Hz. Therefore, Zygo recommends users should set the cutoff frequency to 5.5 kHz (10 times the open loop bandwidth) to eliminate high frequency noise. However, users measuring displacement of fast PZT-based systems may need to have a cutoff frequency much higher than 5.5 kHz.

What is the performance effect of the digital filter on the system servo loop?

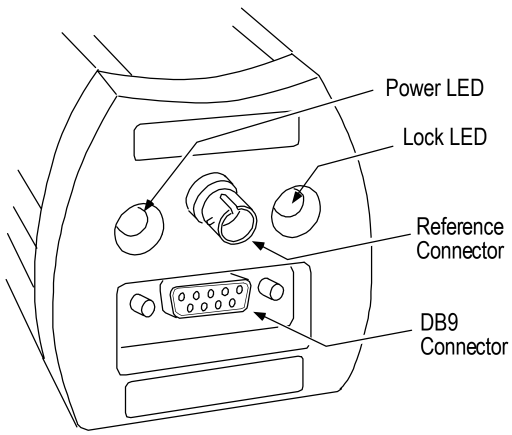
The digital filter will have no effect on the servo loop as long as the selected digital filter cutoff frequency is higher than the open loop bandwidth of the system. It is possible to incorporate the previously provided digital filter transfer function into the stage system's transfer function. The result could then be analyzed for overall system performance.

Laser Head Operation

The Laser Head produces two linearly polarized beams of light, with a wavelength of 632.992 nanometers, which are separated in frequency by 3.65 MHz and coincident in space. The two polarization states are orthogonal to each other. The input voltage to the Laser Head is +15 VDC through the DB9 connector. The measurement output beam is nominally 4 millimeters and the minimum output power is 250 μW.

The Laser Head provides the measurement beam for the ZMI 510 system as well as the reference beam. The measurement beam is directed to the optical components in the system. The reference signal is directed to the Measurement Board via a fiber optic cable.

Laser Head Back Panel

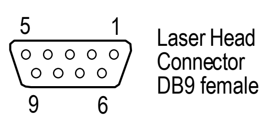


Component	*Description*
Power LED	On when Laser Head receives + 15 VDC.
Lock LED	On when the laser frequency is stabilized and the system is ready for output.
Reference Connector	Connector for fiber optic cable reference signal.
DB9 Connector	Connector for incoming power (+15 VDC) and optional status output.

The Laser Head Locked Signal

The DB9 connector provides power to the Laser Head, plus it provides an output signal when the Laser Head output beam is stable and locked. This signal can be output to the user's control system to indicate when the ZMI 510 is in a ready state. The laser takes approximately 15 minutes to stabilize; wait for the laser to stabilize before making measurements.

Laser Head DB9 Connector Pinout



Pin	*Signal*
1	Locked_P
2	Locked*_P
3	signal gnd
4, 5, and 6	+15 VDC
7 and 8	gnd
9	shield gnd

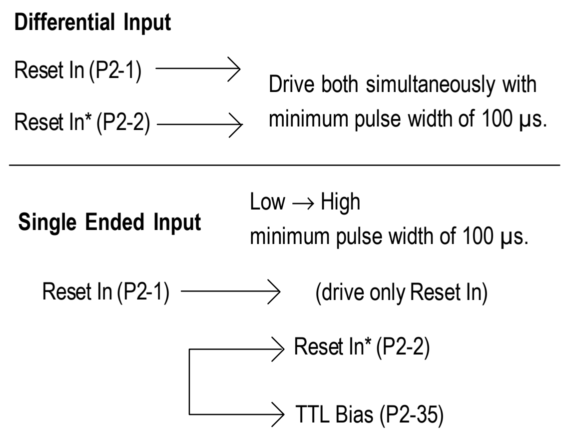
Getting Started

Verify the switch settings of the ZMI 510 Measurement Board; see page 2-2. The Measurement Board requires a +5 VDC supply. The laser head requires a +15 VDC supply. After cables are connected and the optical components aligned, the system is ready to begin outputting position data.

Initialization (or reset)

Supply power to Laser Head and wait for the Laser Head to output the Locked_P signal, which indicates the laser is warmed-up and stable.

Reset the ZMI 510 Measurement Board with a differential input or TTL signal as shown here. After the reset signal(s) are sent, and the target optic moves, quadrature or up/down pulse data is output from the Measurement Board.



Dealing With Errors

If any error signal is output from the Measurement Board to the user's control electronics, the user should examine the ZMI 510 to determine the cause of the error. There are four possible error signal outputs: axis 1 error (P2-5, 6), axis 2 error (P2-8, 9), axis 3 error (P2-11, 12), and measurement error (P2-32, 33). Most errors are usually caused by an improperly aligned optical system, or a beam blockage. Fix the cause of the error and then send a reset signal to the Measurement Board.

Error Signal	*Possible Cause and Fix*
meas err	The reference signal from the Laser Head is missing or the Laser Head is not stable. Ensure that the Laser Head is emitting a reference signal and that the fiber optic cable is connected to the "R" connector on the Measurement Board. Then send a reset signal to the Measurement Board.
axis err	The beam is missing or has been temporarily blocked; or the target optic being measured has moved too fast or accelerated too fast. Ensure that light is emitting from each interferometer; and ensure that the fiber optic cables are correctly installed. If there is no beam to the interferometers or the fiber optic cables are not emitting a beam, check to see if the Laser Head is on and stable, and ensure that the optical components are properly aligned. Then send a reset signal to the Measurement Board.

Theory of Operation

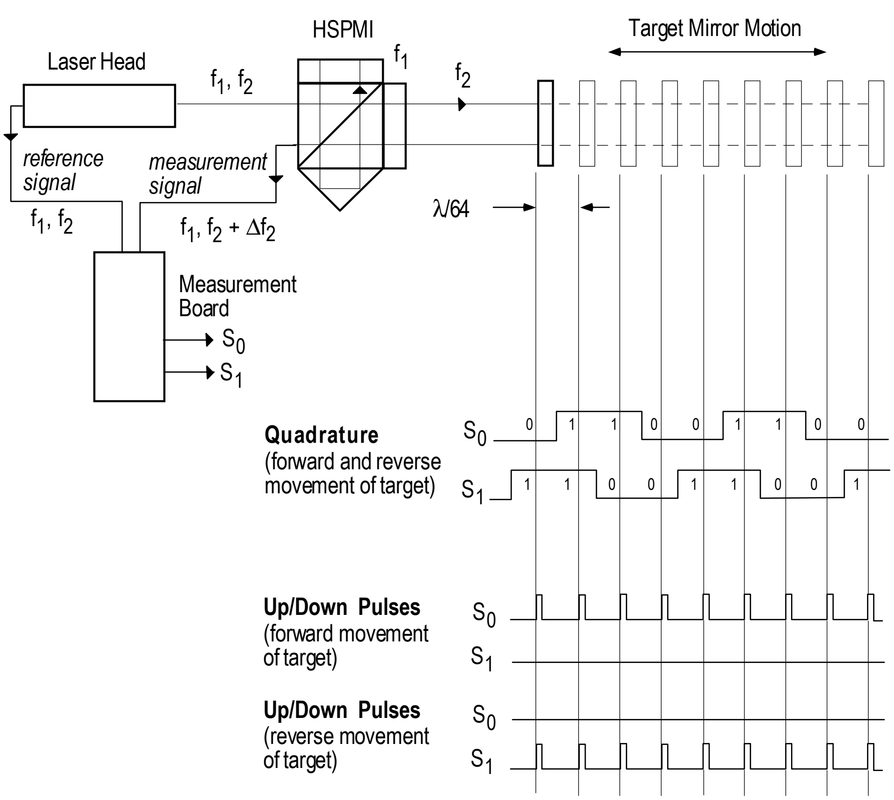
The purpose of the ZMI 510 is to provide position information to the user's servo controller just like that of a typical linear encoder. The ZMI 510 may be configured to output either quadrature or up/down pulses. All output signals are RS-422.

The quadrature output is comprised of two signals (for discussion purposes these will be referred to as S_0 and S_1) that are separated in phase by 90 degrees. The absolute phase angle of S_0, and corresponding absolute phase angle of S_1, is proportional to the position of the target mirror and consequently the frequency of S_0 (and S_1) is proportional to the velocity of the target mirror. By monitoring signals S_0 and S_1, change in the position of the target mirror and the direction of motion can be determined.

The up/down pulse output is simply two signals that pulse independently of each other but dependent on the target mirror motion. One pulse is generated for every least count of the phase measurement electronics.

The high stability plane mirror interferometer is used to define the system resolution. To see a change in phase of the measurement signal with respect to the reference signal of 2π, the target mirror must move by $\lambda/4$. In other words, for every unit displacement of the target mirror, the HSPMI sees four unit displacements. To get a least count resolution of $\lambda/64$ the Measurement Board phase interpolation electronics must resolve the measurement signal into 16 parts, each of which is nominally equal to 9.89 nm ($\lambda/64$).

Measurement Data Output Formats



Maintenance

Chapter
4

In This Chapter

- General Care
- Cleaning Optics
  - Recommended Cleaning Materials
  - Recommended Optic Cleaning Procedures
- Returning Equipment to Zygo

General Care

- *Keep Things Clean*
  The working environment should be as clean, dry, and as dust-free as possible.
- *Handle Optics Carefully*
  Interferometers, fold mirrors, and beamsplitters are precision optics. Handle them only when necessary. Keep unused optics stored in their protective containers. Do not clean optical components unless you have experience cleaning optics.
- *Don't Take Things Apart*
  Do not attempt to dismantle optical parts or repair circuit boards since system performance may be impaired. Do not remove the Laser Head cover, there are no user-serviceable internal parts.
- *Contact Zygo Customer Support Center or Your Zygo Representative*
  Call Zygo or your zygo representative if you have questions or problems.

Cleaning Optics

Cleaning of any precision optic risks degrading the surface. Many of the cleanable optical surfaces are coated. Coated optics are easily damaged by improper or unnecessary cleaning. The need for cleaning can be minimized by proper handling techniques, and by keeping the operating environment clean.

Recommended Cleaning Materials

Material	*Use*
Polyethylene lab gloves	Wear to prevent contamination of surfaces and protect the skin against harsh chemicals.
Blower nozzle	Use compressed gas with blower nozzle to blow off dust and lint from the optic.
Lens tissue	Use optics grade tissue when it is necessary to clean an optical surface.
Cotton swabs	Use to clean difficult to reach surfaces. The swabs should have wood or paper stems; plastic stems can dissolve.
Solvents	Use spectroscopic grade isopropyl alcohol and methanol to remove contaminates fixed to the optical surface. Use a mild, neutral 1% soap solution or lens cleaner to remove oily contaminates.

Recommended Optic Cleaning Procedures

⚠ **Warning!**

- Be careful when using isopropyl alcohol and methanol; both are flammable and toxic.
- Do not reuse any cleaning tissue or pads, reusing tissues can cause contamination and damage to the optic.
- Before cleaning optics, remove all rings and jewelry from your hands and wrists; wash your hands thoroughly to remove excess skin oils; and put on lab gloves.

Optics Cleaning Procedures

Contaminant	*Procedure*
Dust or light dirt	1. Blow off loose particles. 2. If any dust remains, twist two sheets of lens tissue around a swab or fold a lens tissue so it is just wider than the area you are cleaning. 3. Dampen the tissue with alcohol or methanol. 4. Wipe the lens straight across once. If it needs wiped again use a new swab or tissue.
Fingerprints, oil and water spots *Note: Clean surface immediately; skin acids attack lens coatings.*	1. Blow off loose particles. 2. Twist two sheets of lens tissue around a swab or fold a lens tissue so it is just wider than the area you are cleaning. 3. Dampen it with 1% soap solution. 4. Wipe the lens straight across once. If it needs wiped again use a new swab or tissue. 5. Repeat steps 2 and 4 with tissue dampened with distilled water to remove soap residue. 6. Repeat steps 2 and 4 with tissue dampened with alcohol or methanol.

Returning Equipment to Zygo

If it is necessary to return equipment to Zygo for service, please follow the procedure outlined below. You must first contact Zygo to obtain a Return Authorization (RA) number; so that we can route your equipment properly when it arrives. Equipment returned without an RA number is not accepted.

Note: Do *not* return equipment to Zygo without an RA number.

1. Have the following information ready when requesting an RA number:
   - The name of the component and serial number if applicable.
   - Your company's name and complete shipping address.
   - A description of the problem and the sequence of events that led up to your discovering the problem.
2. Contact Zygo by telephone.
3. We will provide an RA number and advise you of the next steps to take.
4. Pack the equipment securely to prevent any damage in shipping. Use the original shipping container and packing material when possible. Include the RA number on the shipping container and on any correspondence.