TITLE

LARGE OPTICS SUSPENSION BALANCING SPECIFICATION

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1 INTRODUCTION

1.1. Objectives and Scope

The scope of this document is to specify how to clean and assemble a Large Optic Suspension. It also details how to prepare an optic for installation into the suspension structure and how to hang and balance that optic.

1.2. Applicable Documents

LIGO-D960132: Large Optic Suspension Assembly, LOS1a
LIGO-D970560: Large Optic Suspension Assembly, LOS1b
LIGO-D970564: Large Optic Suspension Assembly, LOS1c
LIGO-D970572: Large Optic Suspension Assembly, LOS1d
LIGO-D970577: Large Optic Suspension Assembly, LOS1e
LIGO-D970561: Large Optic Suspension Assembly, MMT3, 4k
LIGO-D970578: Large Optic Suspension Assembly, MMT3, 2k
LIGO-D970505: Large Optic Suspension Assembly, LOS2a
LIGO-D970539: Large Optic Suspension Assembly, LOS2b
LIGO-D970507: Large Optic Suspension Assembly, LOS3

LIGO-D960133: LOS Structure Assembly, LOS1
LIGO-D970551: Recycling Mirror Structure Assembly
LIGO-D970506: LOS Structure Assembly, Beamsplitter
LIGO-D970508: LOS Structure Assembly, Folding Mirror

LIGO-D960145: LOS Height Adapter Assembly
LIGO-D970571: LOS1c Height Adapter, Recycling Mirror 4k
LIGO-D970579: LOS1e Height Adapter, Recycling Mirror 2k
LIGO-D970554: LOS2a Height Adapter, Beamsplitter 4k
LIGO-D970555: LOS2b Height Adapter, Beamsplitter 2k
LIGO-D970569: LOS3 Height Adapter, Folding Mirror

LIGO-E960022: LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures
LIGO-T960074: Suspension Preliminary Design
LIGO-T950011: Suspension Design Requirements
LIGO-T970158: Large Optics Suspension Final Design (Mechanical System)
LIGO-L970196: Part Numbers and Serialization of Detector Hardware

2 CLEANING AND BAKING

All procedures listed under Specification for Assembly and Balancing must be performed while suited up in clean room clothing including, but not limited to: coat, booties, bonnet, gloves, facial mask. This applies to anyone handling or near clean pieces or pieces being cleaned. The structure assembly to be cleaned and baked in preparation for installation according to LIGO-E960022, LIGO Vacuum Compatibility, Cleaning Methods and Qualifications.

- **Cleaning Inspection and Testing**

Sample check the cleanliness of blind tapped and through tapped holes with a clean Q-tip dampened with alcohol for a minimum of 10% of the holes. If any discoloration of the Q-tip is evident, then the part must go through at least one more wash before repeating a check of the cleanliness. If any machining chips are found:
(a) a HEPA filtered vacuum cleaner may be used to remove the chips from the holes, and
(b) the holes must be cleaned with a solvent dampened Q-tip wipe.

After inspection and testing, double bag the component in C.P. Stat plastic film. Tie or band the inner bag(s) closed. Do not use tape or heat sealing on the inner bag. Purge the bag with dry nitrogen (class 5 or better) before closing. The outer bag should be heat sealed, after purging with dry nitrogen.

A log of the cleaning procedure shall be kept and form part of the component traveler.

- **Baking Inspection**

Sample check the cleanliness of blind tapped and through tapped holes with a clean Q-tip dampened with alcohol for a minimum of 10% of the holes. If any discoloration of the Q-tip is evident, then the part must go through at least one more wash before repeating a check of the cleanliness. If any machining chips are found:
(a) a HEPA filtered vacuum cleaner may be used to remove the chips from the holes, and
(b) the holes must be cleaned with a solvent dampened Q-tip wipe.

Use ethanol to spot clean any fingerprints.

After inspection, double bag the component in C.P.Stat plastic film. Purge the bag with dry nitrogen (Grade 5 or better) before closing. Tie or band the inner bag(s) shut. Do not use tape or heat sealing. The outer bag should be heat sealed, after purging with dry nitrogen.

A log of the baking procedure shall be kept and form part of the component traveler

- **Clean/Bake Handling**

During and subsequent to the cleaning initiation, all personnel in the cleaning area must wear complete clean room garb, including a lab coat, face mask, hair net/cap, shoe covers and clean room gloves. (This applies to anyone handling or near clean pieces or pieces being cleaned.)

Cleaning to be performed in a “clean manufacturing area” separated from all other operations. This space should have non-shedding floors, walls and ceiling. In addition, the atmosphere for this “clean manufacturing

area" must not exchange directly with the shop floor area; the air must be carbon and HEPA filtered and monitored with a hydrocarbon meter.

Use nitrile gloves (see Appendix 1) for handling cleaned parts. During cleaning with solvents of parts, use a fabric Vidaro Glove (see Appendix 1) over the nitrile glove.

After cleaning and after baking, suspension component surfaces shall not be touched by skin or other contaminants; only C.P. Stat plastic sheet and Nitrilite gloves are acceptable. All suspension parts shall be double bagged (C.P.Stat plastic) or protected by a Class 100 cleanroom atmosphere. Small components can be bagged together with other small pieces. See Appendix 1 for information about the plastic and gloves.

2.1. Quality Assurance/Control

2.1.1. Quality Assurance Provisions

Measure the strength of the magnets using an F. W. Bell Model 9200 Portable Gaussmeter with a Gaussmeter Probe, P/N HTB92-0608 and the Magnet Strength Fixture, P/N D970169 for magnet testing. Collect 8 magnets that have comparable strengths, to within +/- 5%, record the manuf. name, P.O. number, serial/lot number, magnet strength of each magnet and set them aside for one suspension. Use the Large Optic Suspension Assembly Quality Conformance Worksheet to record this data.

Measure the strength of the coils in the sensor/actuator head assemblies using an F. W. Bell Model 9200 Portable Gaussmeter with a Gaussmeter Probe, P/N HTB92-0608 and the Coil Strength Fixture, P/N D970616 for sensor/actuator head assembly testing. Collect six sensor/actuator head assemblies (five needed and one spare) that have comparable strengths, to within +/- 1%, record serial numbers and strengths of each assembly and set them aside for one suspension. Use the Large Optic Suspension Assembly Quality Conformance Worksheet to record this data.

To ensure Quality Conformance for the assembly, complete and file the Large Optic Suspension Assembly Quality Conformance Worksheet, E970132, and keep it with the traveler record for the assembly.

2.2. Fixtures

D961412: Set Screw Tool
D970074: Magnet-to-Dumbbell Standoff Fixture

D970552 LOS2 Magnet/Standoff Assembly Fixture

D960050: Magnet/Standoff Assembly Fixture

D960147: Guide Rod Fixture Assembly

D970574: LOS1b Guide Rod Fixture, ITM 4k

D970568: LOS1c Guide Rod Fixture, RM 4k

D970573: LOS1d Guide Rod Fixture, ITM 2k

D970550: LOS2 Guide Rod Fixture
D960763: Fixture, Test Mass (often called the Dummy Mass)

D970553: LOS2 Test Mass Fixture, BS
38427: Edmund Scientific, Pocket Measuring Microscope

D960016: Microscope Bushing
PZT Buzzer
D950126: LED Fixture
D970180: Winch Fixture
D960145: Height Adapter
D960753: Fixture, Wire and Optics
D960761 Lifting Fixture

- **Set Screw Tool**

Used to ease in the installation of the spring plungers in the Sensor/Actuator Plates.

- **Magnet-to-Dumbbell Standoff Fixture**

Used to configure and bond the magnets to the dumbbell shaped aluminum standoffs.

- **Magnet/Standoff Assembly Fixture**

Used to position and epoxy the magnet/standoff assemblies to the face of the optic.

- **Guide Rod Fixture**

Used to position and bond a guide rod, a wire standoff and side magnet/standoff assemblies to the side of the optic.

- **Fixture, Test Mass**

Used for the prototype test. This aluminum “optic” has the same size, wedge, chamfer and approximate mass as the fused silica optic.

- **Measuring Microscope**

Used to align the sensor/actuator plates to the magnet/standoff assemblies glued on the optic or dummy mass.

- **Microscope Bushing**

Mounted on the bore of the measuring microscope and used to adapt the bore of the microscope to the bore of the holes for the sensor/actuator head assemblies in the sensor/actuator plates. This bushing is also used to align the centerline of the microscope (crosshairs) to the centerline of the outside diameter of the bushing.

- **PZT Buzzer**

Used for sliding the wire standoff along the side of the optic to change the pitch balance of the optic. It is a rod or tube to which a PZT is attached. The PZT is driven while the vibrating rod is placed against the end of the standoff to produce small displacements of the standoff.

- **LED Fixture**

Used to position and mount the LED relative to the photodiode in the sensor/actuator head. Use of this fixture will be covered in another document

- **Winch Fixture**

Just as the name implies, this fixture is used to microposition the suspension wire vertically.

- **Height Adapter**

Used to adapt suspension to its correct vertical position relative to the laser beam.

- **Fixture, Wire and Optics**

Used to position the wire and to protect and move the optic into position in the suspension support structure.

- **Lifting Fixture**

Mounted to a fork lift, this fixture allows for the assembly to be moved into place on the optical table.

2.3. Assembly/Balancing Specification

2.3.1. Assembly Sequence

1. Suspension Assembly
2. Optic and Dummy Mass Preparation
3. Optic Hanging and Balancing
4. Sensor/Actuator Head Installation

2.3.2. Suspension Assembly

1. Clean and bake all components of the suspension assembly, except the suspension wire, per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022
2. Screw in the 8 Wedge Stops and the 8 3/8” bolts into their respective brackets until they protrude past the inside of the bracket by about .25”.
3. Install the spring plungers, or the alternate socket head set screws, into the Sensor/Actuator Brackets in preparation for the installation of the Sensor/Actuator Assemblies. The Set Screw Tool may be used with the cross head spring plungers instead of a regular screw driver.
4. Install the suspension block with its hardware. Do not install the clamps on the suspension block just yet.
5. At this point, prepare the optic for installation using the fixtures and procedure below. Note, although the height adapter is part of the assembly, if it is installed before the optic is suspended, access to the suspension block is awkward at best and impossible at worst. Instructions for bolting the height adapter to the suspension structure are included under the Optic Hanging and Balancing step.

2.3.3. Optic and Dummy Mass Preparation

2.3.3.1 Magnet-to-Dumbbell Standoff

- **Materials**

D960501: Magnet
D970075: Dumbbell Standoff
D960149: LOS Side Standoff or appropriate
Perkin Elmer Vac-Seal epoxy resin
D970074: Magnet-to-Dumbbell Standoff Fixture or appropriate
solvents; methanol, acetone, isopropyl alcohol
6” length of 20 to 30 ga insulated wire
800 grit sandpaper
cellophane tape
oil-free aluminum foil
lint-free wipes
microscope
ultrasonic agitator

- **Adhesive Procedure**

1. Prepare magnets and standoffs: Clean 9 magnets and 9 standoffs (6 regular and 3 side standoffs), separately, per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022. Lightly sand both ends of each magnet with 800 grit sandpaper. Use cellophane tape to remove the grit. Using a microscope, examine the sanded magnet ends to make sure that all grit has been removed. Clean the magnets in an ultrasonic agitator with acetone. Check the ends of the standoffs under the microscope to make sure that each surface is clean, flat and without burrs. If a surface looks unsatisfactory, follow the magnet sanding instructions for both ends of the standoffs.
2. Prepare adhesive applicator: Strip off about 0.5” of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol with lint-free wipe.
3. Prepare epoxy: Mix the two epoxy components of a Vac Seal “bipax” together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean oil-free aluminum foil.
4. Install magnets in fixture: Insert eight magnets into the magnet-to-dumbbell standoff fixture after it has been cleaned thoroughly with methanol and acetone. The magnets have to be positioned on the optic so that their polarities are alternated. It is best to make six magnet/standoff assemblies of one polarity, using three regular standoffs and three side standoffs, and three of the other polarity with regular size standoffs. The easy way to do this is to line up the nine magnets to be used with this fixture. Insert six magnets in six holes, and then turn the magnets in your hand 180 degrees, and then insert the last three in the remaining holes. Using Table 1 in the QC Worksheet, D970132, note which magnets are which polarity. A “Master Magnet” may be used to determine polarity. Simply mark the ends of a magnet with a “+” on one end and a “-” on the other end using paint or nail polish.
5. Apply epoxy: Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the end of a standoff. Optimum adhesive thickness is.003” [.08mm] or a volume of 3.9×10^{-6} in^3 [.06mm^3]. Epoxy should only cover a diameter of about.02” [.5mm]with a height of

.01"[.3mm]. Insert standoff carefully into fixture, making sure not to get adhesive on fixture. Repeat this for remaining standoffs, making sure to use 3 longer dumbbell standoffs for the side magnets, as shown on the LOS Assembly parts list. Lightly tap the standoffs against the magnets.

6. Cure epoxy: Leave the assembly, standoff side up, for 24 hours or more. Vac Seal cures in 72 hours so if that time is available, it should be used to allow the assemblies to fully cure.
7. Remove from fixture: Use a blunt, clean, non-magnetic instrument to tap the magnets and remove the assemblies. Take care to move each assembly away from the fixture, and apart from each other, after loosening. Move the assemblies onto a clean, flat plate separating the ones with the longer standoffs.**Take great care when handling these glued assemblies as they are extremely fragile.**
8. Ultrasonic clean assemblies: Place plate with magnet/standoff assemblies into an ultrasonic agitator filled with isopropyl alcohol for 10 minutes.

2.3.3.2 Magnet/Standoff Assembly Fixture

- **Materials**

9 magnet/dumbbell standoff assemblies, from instructions above.
Perkin Elmer Vac-Seal epoxy resins
D960050: Magnet/Standoff Assembly Fixture or appropriate
D960147: Base Plate of Guide Rod Fixture Assembly or appropriate
D960763: Fixture, Test Mass (Dummy Mass) or Optic or appropriate

Kapton film, 0.0075" thick
solvents; methanol, acetone, isopropyl alcohol
6" length of 20 to 30 ga insulated wire
oil-free aluminum foil
lint-free wipes

- **Fixture Assembly**

1. Clean fixtures: Clean base plate of guide rod fixture and magnet/standoff assembly fixture thoroughly per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022.
2. Clean optic: Clean optic thoroughly to remove heavy contamination per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022.Care must be taken to clean the outside of the optic.
3. Position optic on fixture: Cut three small strips (.50" x 1.00") and place on the etched circle in the base plate. This Kapton is used to protect the bottom face (the high reflective surface) of the optic. Glue the Kapton in place with Vac Seal. Place the optic or dummy mass onto the Kapton on the base plate with the side up that will have the magnet/standoff assemblies epoxied to it. Magnets are glued onto the anti-reflective side of the core optics. If you do not wish to have the left and right blocks of the guide rod fixture in place at this time, be sure to place a 0.50" min. plate under the base plate to allow for those blocks to be moved along the dovetail grooves at a later time. Configure the optic such that its outer diameter lines up evenly with the circle etched onto the base plate. Using the arrow on the side of the optic, rotate the optic until the arrow lines up with the horizontal and/or vertical lines of the base plate, whichever is appropriate for the positioning of the optic with respect to the face magnets. See T98 for magnet configuration data.

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4. Prepare the magnet/standoff fixture: Make sure the two #4-40 screws that hold the two pieces of the fixture together are in place and tightened. Install the three #10-32 set screws on the side of the bottom piece of the fixture (called the holding ring) until the tips are flush with the inside diameter of the holding ring. Position the two screws with knobs so that the tip of the screws just touch the holding ring. Mark a line on the top of each knob from the centerline to the outside diameter to determine initial rotation position. The lines on the knobs should be parallel to each other.
5. Mount the magnet/standoff fixture: Carefully lower both onto the face of the optic such that the top piece of the fixture (called the positioning ring) registers onto the top surface of the optic. Align the lines on the outside diameter of the fixture with the etched lines on the side of the optic. Using the three side set screws, position the fixture such that its centerline is coincident with the centerline of the optic as close as possible. This is done by incrementally advancing the set screws. Make sure that the fixture doesn't slip from its alignment with the lines on the optic.
6. Prepare the adhesive applicator: Strip off about .5" of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol with lint-free wipe.
7. Prepare the epoxy: Mix the two epoxy components of a Vac Seal "bipax" together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean oil-free aluminum foil.
8. Apply the epoxy: Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the end of a standoff. Optimum adhesive thickness is .003" [.08mm] or a volume of 3.9×10^{-6} in^3 [$.06mm^3$]. Epoxy should only cover a diameter of about .02" [.5mm] with a height of .01"[.3mm]. Insert standoff carefully into fixture, making sure not to get adhesive on fixture. Repeat this for three more magnet/standoff assemblies. Make sure that the magnet's poles are in opposite configuration to the magnet next to it in the circle. For example, see Figure 1 below. Lightly tap the top of the magnets. The magnets are placed so that polarities of the magnets alternate; this is to prevent the mass from being shaken in position and orientation, by time-varying ambient magnetic fields.
9. Cure epoxy: Leave the assembly for 24 hours or more. Vac Seal cures in 72 hours so if that time is available, it should be used to allow the assemblies to fully cure.
10. Remove magnet/standoff fixture: After curing, remove the two #4-40 screws that hold the positioning ring to the holding ring. Incrementally turn the knobs of the two #10-32 screws, at the same time, so that the positioning ring slowly rises above the holding ring without tilting. When the positioning ring has cleared the magnet/standoff assemblies, carefully set it aside and again, carefully, remove the holding ring from the optic. Maintain the position of the optic on the base plate as it will need to be in this position for the guide rod fixture assembly procedures, below.

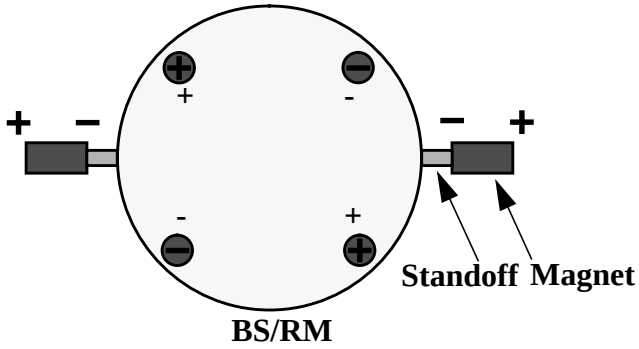

Figure 1: Configuration of the magnet/standoff Assembly.

2.3.3.3 Guide Rod Fixture

- **Materials**

Dummy Mass or Optic with four magnet/standoff assemblies glued to its face
2 or more magnet/standoff assemblies of the same pole configuration that use the side (longer) dumbbell standoff
D960755 LOS Large Wire Standoff or appropriate
D960146: Guide Rod
Perkin Elmer Vac-Seal epoxy resin
D960147: Guide Rod Fixture Assembly - which includes: or appropriate
  Base Plate
  Left Block, Top
  Right Block, Top
solvents; methanol, acetone, isopropyl alcohol
6” length of 20 to 30 ga insulated wire
oil-free aluminum foil
lint-free wipes

- **Fixture Assembly**

1. Check optic alignment: Check to make sure that the optic or dummy mass is centered in the etched circle on the base plate of the guide rod fixture. If the parts are separate, review step #2 of the magnet/standoff fixture assembly, above. Check the outside diameter of the optic for cleanliness. If marks are present, clean it with the appropriate solvent and lint-free wipes. Take care to keep solvent away from the epoxied magnet/standoff assemblies.
2. Prepare fixture and parts: Clean the blocks of the guide rod fixture thorougly per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022. Clean and bake the guide rod and wire standoff per the same specification.
3. Align optic in fixture: Carefully slide the two top pieces; left block, top and right block, top along the

wedges of the base plate. Snug them up against the side of the optic and tighten the screws that hold the top blocks to the base plate to finger tightness.

4. Check polarity of magnets: Check that the magnet/standoff assemblies that will be used with this fixture are of the same pole configuration (i.e. the positive pole is glued to the standoff) as shown in Figure 1.
5. Prepare adhesive applicator: Strip off about .5" of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol with lint-free wipe. If using an adhesive applicator that was previously used, be sure to clean off all old, cured adhesive.
6. Prepare epoxy: Mix the two epoxy components of a Vac Seal "bipax" together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean oil-free aluminum foil.
7. Position and glue the wire standoff and guide rod: Position the guide rod in the smaller vertical v-groove. If there is difficulty inserting the guide rod into the v-groove, move the top block down a bit, along the wedge, insert the guide rod, and then cinch the block back into position, holding the guide rod in the v-groove securely. Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the vertical line of contact between the guide rod and the optic that is furthest away from the magnet/standoff assembly. Be sparing in epoxy at this point as more glue will be used later to secure this guide rod. Take care in not getting epoxy on the fixture. Insert the wire standoff in the other vertical v-groove and apply epoxy in the same way. Be sure to apply epoxy to the vertical line of contact between the wire standoff and the optic that is furthest away from the magnet/standoff assembly.
8. Glue the magnet/standoff assemblies: Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the end of a side (longer) dumbbell standoff. Optimum adhesive thickness is.003" [.08mm] or a volume of 3.9×10^{-6} in^3 [.06mm^3]. Epoxy should only cover a diameter of about.02" [.5mm] with a height of .01"[.3mm]. Push magnet/standoff assembly slowly and carefully along the larger horizontal v-groove, making sure not to get adhesive on fixture. Repeat this for the magnet/longer standoff assembly on the other side of the optic. Lightly tap the end of the magnets.
9. Check the adhesive joints: If preparing an optic rather than a metal dummy mass, look through the optic at the four glue joints and make sure that the contact area is visible.
10. Cure epoxy: Leave the assembly for 24 hours or more. Vac Seal cures in 72 hours so if that time is available, it should be used to allow the assemblies to fully cure.
11. Remove the guide rod fixture: After curing, unscrew the fasteners that hold the top blocks to the base plate, one side at a time, and slowly, carefully, move the top blocks down the wedges and out of the way of the magnet/standoff assemblies and the guide rod and wire standoff.

2.3.4. Optic Hanging and Balancing

- **Materials**

Optic or dummy mass with 6 magnet/standoff assemblies and 1guide rod and 1 wire standoff glued to it.
Large Optic Suspension Structure
.012" diameter suspension wire
D960755: Large Wire Standoff or appropriate
D970180: Winch fixture
HeNe laser
Quad photodiode
Table level

Perkin Elmer Vac-Seal epoxy resins
6” length of 20 to 30 ga insulated wire
oil-free aluminum foil
lint-free wipes
38427 Edmund Scientific, Pocket Measuring Microscope
D960016: Microscope Bushing
PZT Buzzer
D960753: Fixture, Wire and Optics
Base Plate
Cradle
Teflon Bracket
Metal Brackets
Teflon Strap
D960145 Height Adapter or appropriate
18 1/4-20x1.50 long stainless, SHCS (LOS2 assemblies will use more hardware, see top assembly)
18 1/4-20 stainless lock washers
18 1/4-20 stainless flat washers
18 1/4-20 hex nuts
solvents: methanol, acetone

- **Assembly**

1. Prepare the wire standoff and suspension wire: Clean and bake the other wire standoff per LIGO Vacuum Compatibility, Cleaning Methods and Qualifications Procedures document, LIGO-E960022. The suspension wire should not be baked - only cleaned. Be sure to clean the wire thoroughly by wrapping a solvent soaked lint-free wipe around the wire and gently pulling the wire through the wipe. This should be done a minimum of three times to remove any rust and contaminants.
2. Make an optical lever: Level the optical table that’s being used for this suspension work, using a mechanical bubble type level, within +/- 0.05 mrad. Set up an optical lever, using a small HeNe laser and a quad cell photodiode, and level the beam within +/- 0.05 mrad. Refer to D960752 for drawing of an optical leveler. This is done by placing the photodiode near the output of the laser and centering the photodiode to the laser beam. Then move the photodiode down the table and measure the angular displacement of the beam. Make the lever arm as long as possible to increase the accuracy of the alignment.
3. Prepare the winch fixture: Using oversize washers and a 1/4-20x1.25” long screw, attach the winch to one of the threaded holes on the top of the suspension block, with the rocker of the winch closest to the front of the suspension block. Attach one top suspension block clamp to the top of the suspension block with its screws holding it loosely in place. Attach the other suspension block clamp to the face of the winch, keeping the screws loose. Attach the bottom two suspension block clamps to the suspension block with its screws, leaving the clamps loose.
4. Move optic into place: Clean the wire and optics fixture components. Thoroughly clean suspension wire with methanol and acetone if it has not been done within an hour or so beforehand. Place the wire in the groove in the cradle of the fixture. Take care not to twist the wire. Any twist in the wire will greatly affect the balance. Make sure that the base plate is positioned under the cradle. Carefully sit the optic in the cradle over the wire, such that the face of the optic that has the magnets/standoff assemblies glued to it is pushed

up against the back-stop of the cradle. Clamp the optic in place with the Teflon bracket, the metal brackets and the Teflon strap on top. Slowly push the cradle into the suspension structure. Using the safety stops under the optic, lift the optic 0.04" above the fixture and remove the brackets. Move the cradle out of the way, moving it away from you. Screw in the chamfer stops so that there is a 1-2mm gap between the optic and the end of the chamfer stop.

5. Thread the wire around the optic: String the wire up to the suspension block and under the bottom two suspension block clamps. Secure the wire with the clamps, finger tight, such that it is touching the inside of the dowel pins pressed into the suspension block. Remember that it is undesirable to have any twist in the wire.The purpose of the two bottom suspension block clamps at this point is only to keep the wire against the face of the suspension block. In the process of threading the wire, be sure to keep the wire clear of the magnet as the wire is magnetic. Slip the wire under the top clamp on the suspension block and tighten the clamp's screws. Slip the other end of the wire under the winch clamp, making sure to snug the wire against the dowel pin. Tighten the screws for the clamp mounted to the winch after lightly pulling on the wire.
6. Prepare to suspend the optic: Position the wire such that it is slightly taut by threading in or backing off of the winch's 1/4-20 screw. By eye, align the centerline of the magnets with the centerline of the holes in the sensor/actuator brackets. Insert a wire standoff below the guide rod, making sure that the wire sits in the v-groove of both of the wire standoffs. The wire standoff may be inserted above the guide rod and then moved down over the guide rod into place below it. If this approach is used, be sure to loosen the wire a bit so that the wire will not break or the guide rod will not break off due to increased tension in the wire.
7. Suspend the optic: Slowly, lower the safety stops that support the bottom of the optic and suspend the mass. Try backing off the face safety stops to determine which direction the wire standoff needs to slide along the guide rod to balance the optic/dummy mass. Use the PZT buzzer to micro-position the wire standoff so that the optic/dummy mass will hang stationary. When repositioning the wire standoff, be sure to clamp the optic/dummy mass with the safety and chamfer stops. Again, check the position of the optic making sure that the centerlines of the magnet/standoffs on the face of the optic line up with the centerline of the holes for the sensor/actuator head assemblies in the sensor/actuator plates. Adjust the height of the optic with the winch if necessary. Check often that the wire is still in the grooves of the wire standoffs.
8. Balance the optic: Refer to LIGO-T970091 and LIGO-T98 to determine the proper optic orientation. Using the optical lever, balance the optic such that the unbalance is **within +/- .5 mrad**. Test the balance by rotating the mass around the optical axis, +/- 20 degrees. Before rotating the optic, be sure to move the safety stops below the optic into position such that the optic is lightly supported by these stops. This will allow the wire to loosen a bit when the optic is rotated. After rotating the optic a number of times, check the balance. Use the microscope in the sensor/actuator holes to align the optic to the holes.
9. Mount microscope bushing to microscope: Align the centerline of the microscope to the centerline of the microscope bushing. To do this, start by mounting the bushing onto the microscope bore as evenly as possible, using one row of set screw holes. Position the bushing in an optical mount so that the other row of set screws is accessible. Mount a fiber optic beam delivery cable, connected to a high intensity lamp, into another optical mount and position it so that the light passes through the microscope and illuminates the cross hairs at the focal length. Remember that this type of microscope will show an inverted image. Use a piece of paper, mounted on a flat vertical plate, to image the cross hairs at the focal length. Slowly rotate the microscope to determine the magnitude of the displacement between the centerline of the microscope cross hairs and the centerline of the bushing outer diameter. Using the accessible set screws, reduce the displacement as much as possible between the two centerlines. Use a threadlocker or tape on/around the adjust-

ment set screws to indicate that this alignment has been performed.

10. Use microscope to position the optic: Mount the bushing/microscope assembly into one of the holes for the sensor/actuator head assembles and view the position of the magnet relative to the position of the sensor/actuator hole. Insert the bushing/microscope in the hole next to it and determine the position of the magnet/standoff assembly relative to the sensor/actuator hole. Carefully lift the optic, by holding its on the sides, off of the bottom safety stops, and rotate the optic to line up the magnets with the holes. Remember that the sensor/actuator brackets on the suspension structure have been fabricated to be in line with the optic in its balanced tilted position.
11. Gently clamp optic: When the optic is balanced, gently move the chamfer stops near the face of the optic, just until contact is made. Make sure that the alignment doesn't change. [If the optic is fully clamped, the alignment will change upon the adhesive curing.]
12. Prepare adhesive applicator: Strip off about .5" [12mm] of insulation from the wire. Splay conductors and clip off all but one. Clean conductor with acetone and alcohol using a lint-free wipe.
13. Prepare epoxy: Mix the two epoxy components of a Vac Seal "bipax" together thoroughly, approximately 2 minutes. Dispense from the middle of the container onto clean oil-free aluminum foil.
14. Apply epoxy: Dip conductor wire in epoxy and withdraw it, leaving a tiny amount of epoxy on the wire. Apply epoxy on the wire to the top side and ends of the wire standoff. Apply epoxy to the unglued end of the opposite wire standoff to secure it better.
15. Cure epoxy: Let the suspension sit for 72 hours or more.
16. Inspect, bake and clean optic: If balancing an optic (rather than a dummy mass) for installation into an interferometer, remove the optic from the suspension being careful not to break off the magnet/standoff assemblies or the guide rods or wire standoffs in handling. Try not to break the suspension wire upon removal of the optic. Carefully inspect the surface of the optic for cleanliness. If the optic exhibit contaminants, clean for light contamination per LIGO-E960022. Care should be taken to keep the solvents away from all glue joints as acetone will dissolve Vac Seal. Bake the optic per that same specification. After baking, clean the optic for light contamination per LIGO-E960022 to remove outgassing contaminants from the epoxy.
17. Re install the optic: Rehang the optic, with the same suspension wire, and make sure it is has maintained its balance using the optical lever.
18. Check balance: Determine if this alignment is satisfactory by assuming a maximum vertical positional offset is 500 microns and the maximum horizontal offset is 300 microns. These offset assumptions are valid for a sensor/actuator head assembly that has the LED and photodiode oriented vertically. If the optic is still misaligned vertically from the sensor/actuator plates, use the winch to adjust its vertical position. If the optic is misaligned rotationally, prop it up with the safety stops under it, and gently rotate about the centerline of the optic. The optic may have to be rotated a number of times to position the wire in the same way it was before baking the optic.
19. Tighten suspension block clamps: Tighten the screws for the bottom suspension block clamps. Tighten the top suspension block clamp. Remove the clamp from the winch and screw it into the suspension block, aligning the wire against the dowel pin. Remove the winch. Recheck all clamp screws to make sure the wire is secure.
20. Prepare and mount height adapter: Clean and bake the height adapter per LIGO-E960022 and bolt it to the Large Optic Suspension Assembly with the hardware listed above. Make sure that the hardware has been cleaned and baked per LIGO-E960022. Torque all fasteners to 100 in lb.

2.3.5. Sensor/Actuator Head Installation

- **Materials**

suspension
D960138: Sensor/Actuator Assembly
D970615 PAM Screws
D970501 Magnets
Perkin Elmer Vac-Seal epoxy resin
Kapton sensor/actuator cables
solvents; methanol, acetone, isopropyl alcohol
solder and flux
deflux spray

- **Assembly**

1. Prepare the sensor/actuator heads and cables: Clean the assemblies along with the cables per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022.
2. Mount the sensor/actuator heads: Install the 4 cleaned and baked #10-32 set screws or spring plungers in the threaded holes that will hold the sensor/actuator assemblies in place until they are flush with the inside diameter of the sensor/actuator assembly mounting hole in the sensor/actuator bracket. Solder the cables to the wires coming out of the pins on the pin plates. Deflux the solder joints.Mount the sensor/actuator assemblies in the proper configuration, making sure that the optic/dummy mass is fully clamped. Slowly, slide the sensor/actuator assemblies into the holes in the bracket until about 2mm of sensor/actuator assembly protrudes beyond the back of the sensor/actuator brackets.
3. Optimally position the heads: Using an oscilloscope, optimally position the sensor/actuator assemblies with respect to the magnet/standoff assemblies on the optic. This is done by measuring the voltage of the unblocked photodiode and then positioning the sensor/actuator head such that the magnet shadows the photodiode and produces half of the unblocked voltage. Use the set screws to clamp the sensor/actuator assemblies in their optimum positions. **Always check the position of the safety stops as a gap of 1mm must be maintained to protect the magnet/standoff assemblies during this procedure**.
4. Optimally position the heads rotationally: Check the calculated vertical resonance for the wire. The orientation of the LED/photodiode pair in each sensor/actuator head affects the magnitude of this resonance's coupling into the pitch and yaw resonant frequencies. While moving the sensor/actuator head assemblies near the magnets on the optic, check the orientation of the sensor/actuator head assemblies. Generally, the optimum position is near to vertical, in that the photodiode is directly over the LED in a vertical orientation. If the oscilloscope shows a sharp spike around the calculated vertical resonance, slowly rotate the head assembly until the spike is at a minimum. Generally this is within 20 degrees of the vertical.
5. Install the PAM screw: Check that the sensor/actuator assemblies damp properly and that critical damping may be achieved. If optic has become unbalanced, pitch alignment magnet (PAM) screws may be used. Clean the screws and magnets per LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures, LIGO-E960022. Using Vac Seal, epoxy magnets into the counterbore of the PAM screws. Allow for the epoxy to completely cure. Screw the assembled PAM screws into the back of the sensor/actuator assemblies, very carefully.

TITLE

LARGE OPTICS SUSPENSION BALANCING SPECIFICATION

APPENDIX 1

- **C.P. Stat Plastic Film for wrapping and bagging**

C.P. Stat 100 ESD sheeting,
1 roll 48” wide by 1000 ft. long,
with CFC certification that it passes
JPL’s specifications.

Caltex Plastics, Inc.
P.O. Box 58546
2380 E. 51st St.
Los Angeles, CA 90058
213-583-4140

- **Inpro-Clean 1300 for cleaning stainless steel**

Oakite Products, Inc.
Berkeley Heights, NJ
800-899-8074

- **Mirachem 500 for cleaning stainless steel**

The MIRACHEM Corporation
2113 East Fifth Street
Tempe AZ 85281-3034
800-662-0333

- **Nitrile Gloves for handling hardware**

Ansell Edmont Industrial, Inc.
Coshocton, OH 43812
614-622-4311

- **Vidaro gloves for use with solvent cleaning**

part nos. 2-MY-31K4-2 or 2-WY-31K4-2
Vidaro Corporation
Kent OH 44240
330-673-0228