

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY  
- LIGO -

CALIFORNIA INSTITUTE OF TECHNOLOGY  
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| <b><u>LIGO Detector Subsystem Review Report</u></b><br><b>Core Optic Components Shipping &amp;<br/>Handling Procedures</b> |                          |                             |
| <i>Title</i>                                                                                                               |                          |                             |
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# **1 Scope**

The LIGO core optic components (optics) are extremely sensitive to environmental conditions and physical handling. They have been fitted with special “Core Optic Component Carriers” (carriers) and shock absorbing shipping containers for general transportation and storage. This document serves as a procedural guide for handling of these components from receiving through unpackaging of the carrier, removal of the optic from the carrier, laboratory processing of the optic, replacement of the optic into the carrier, repackaging of the carrier, shipping, and storage. All personnel who handle LIGO optics and carriers shall be familiar with this document and follow its guidelines.

# **2 Handling Procedures**

**Preliminary Note:** All handling and processing of LIGO optics and carriers, other than initial receiving and final shipping, shall be performed by qualified personnel wearing class 100 clean-room garments: nitrile gloves, cap or hair net, nose and mouth mask, smock, and booties. Gloves shall be replaced whenever possible contamination occurs, or a new process is begun. All tools and equipment used shall be clean per LIGO-E960022. No particulate shedding materials, e.g. Kimwipes, shall be used. All processing of optics shall be performed on a class 100 laminar flow bench and in accordance with LIGO specifications. The central 23 cm (optics are 25 cm in dia.) of each optical face shall be kept free of contact by anything other than the laboratory atmosphere, except during surfacing operations or cleaning. Each optic shall be placed only in its specifically designated carrier. For this purpose, each carrier bears an external tag which bears the serial number of the optic assigned to that carrier. The optic’s serial number is etched on its cylindrical side, i.e. FM03 for Folding Mirror number 3. The carrier, of which there are two types: P/N D961460 for the larger optics, and D961461 for beam splitter optics, bears an identical engraved number on each of its three separable main components - the carrier body, the top plate, and the cover. This number consists of the basic P/N followed by a three digit serial number, i.e. D961461 S/N 003. Each carrier must always be assembled of components with matched part and serial numbers.

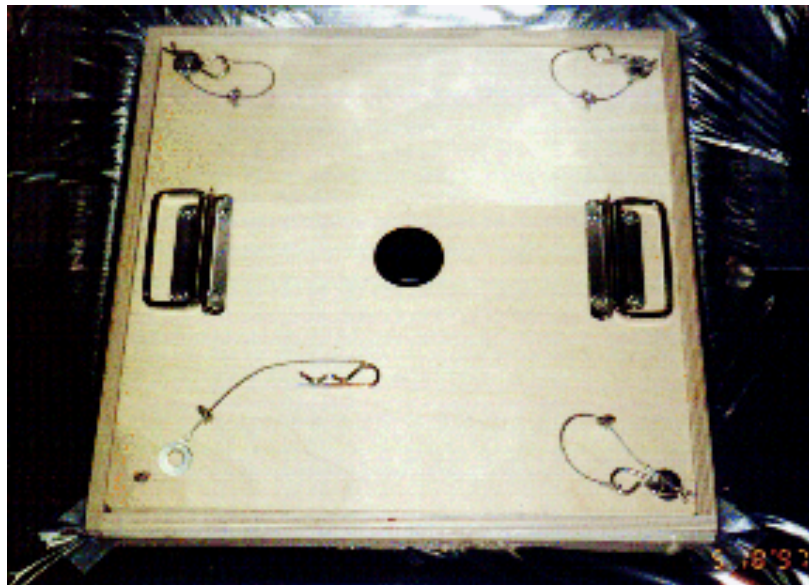
## **2.1. Receiving**

The LIGO optics and carriers are shipped in high impact, shock absorbing shipping containers (Figure 1). Manual transporting of shipping containers containing LIGO optics shall be performed carefully, by two persons at all times.

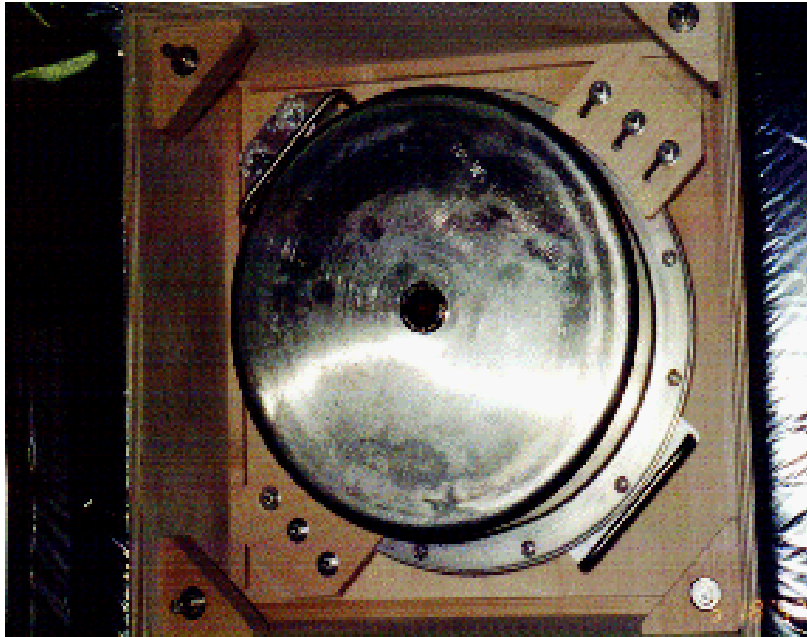
Upon receipt, transport the shipping container(s) directly to a location near the processing area. Observe the condition of the shipping container(s) exterior for any signs of distress or damage. Open each shipping container, disengage the four hold-down pins of the inner wooden compartment lid (Figure 2), and remove the lid. Do not attempt to remove the inner wooden compartment (Figure 3) from the shipping container. Visually inspect each carrier and check the two shock indicators (60g & 150g) at the bottom of the wooden compartment, making sure that the spring-ball mechanisms are not sprung (Figure 4). Record any discrepancies and/or sprung shock indicators on the shipping receipt before signing. Include the serial number of each affected carrier. Notify the cognizant LIGO Detector Group Engineer.



**Figure 1: Shipping Container**



**Figure 2: Shipping Container Inner Compartment with Lid**



**Figure 3: Shipping Container Inner Compartment**



**Figure 4: 60g & 150g Shock Indicators**

## **2.2. Unpackaging the Carrier**

To remove the carrier from the shipping container, loosen the three socket screws on each hold-down clamp in the wooden compartment (bottom photo, previous page). Slide the slotted

clamp all the way back away from the carrier, then remove the carrier and place it on a work surface for external cleaning.

To clean the carrier exterior, wipe all outer surfaces, including the viton feet, with a dry clean-room grade lint free polyester cloth (“cleanwipe”). Put on nitrile gloves and repeat wiping metal surfaces with a new cleanwipe soaked with methyl alcohol. Do not let methyl alcohol drip into the vacuum/pressure relief valve. Take the carrier directly to the processing area for processing or pre-storage cleaning of the optic. See note in section 8 regarding optics which are to be stored directly upon receipt from shipping.

### 2.3. Removal of the Optic From the Carrier

**Note:** Minimize travel of the optic when unprotected. The optic shall not be moved more than ten feet (3 m) when outside of the carrier. Always plan for minimized motion before removing optics from carriers.

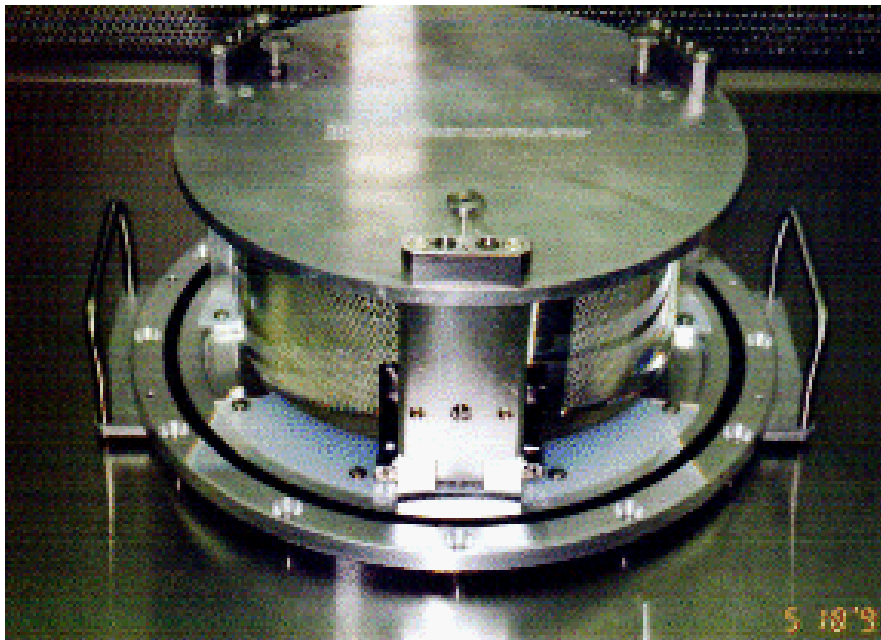


**Figure 5, Note:** The pressure/vacuum release valve shown being manually depressed has been excluded as of revision C of both carrier designs.

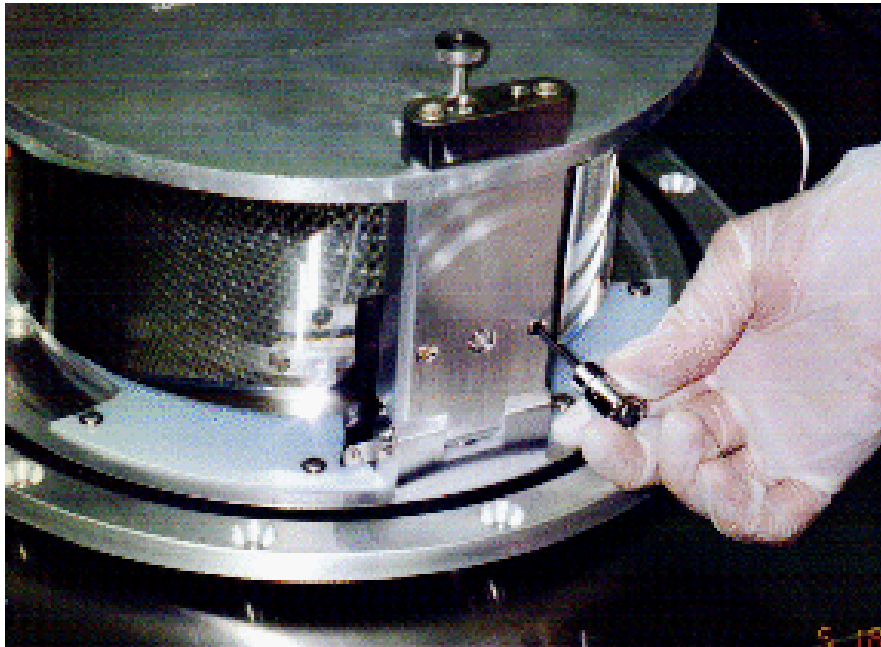
After exterior cleaning, move the carrier to a class 100 laminar flow bench within the processing area. Disengage the 12 quarter turn locks around the base (Figure 6). Remove the cover (Figure 7). Always set the cover right side up on a clean flow bench surface. Back off the two set screws in the hinged upright member to unload the teflon side pad (Figure 8). Do not back off the set screws in the two stationary (non hinged) upright members. The teflon side pads on the stationary upright members need only be adjusted at the original fitting of the carrier to the optic (see note, section 2.5., pp. 13).



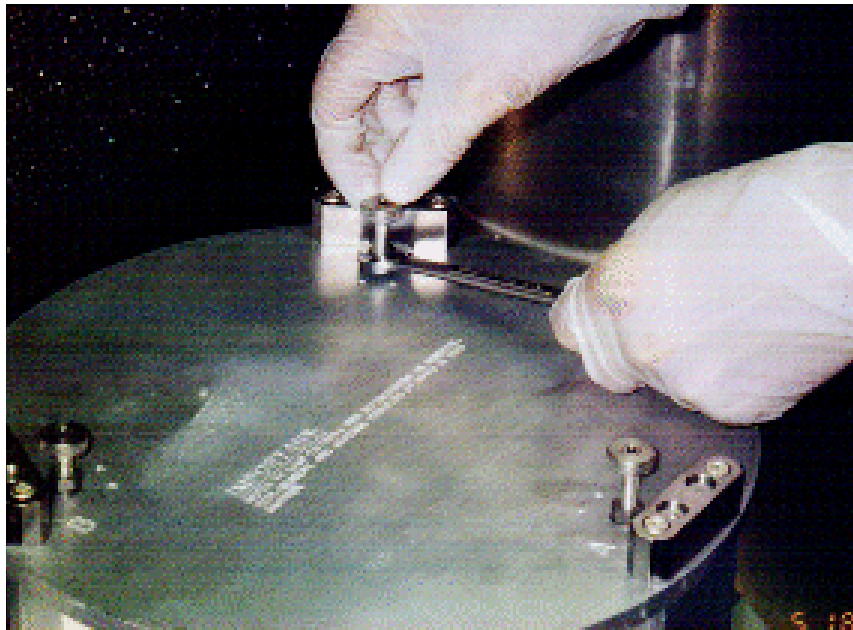
**Figure 6: Disengaging the Cover**



**Figure 7: Cover Removed**



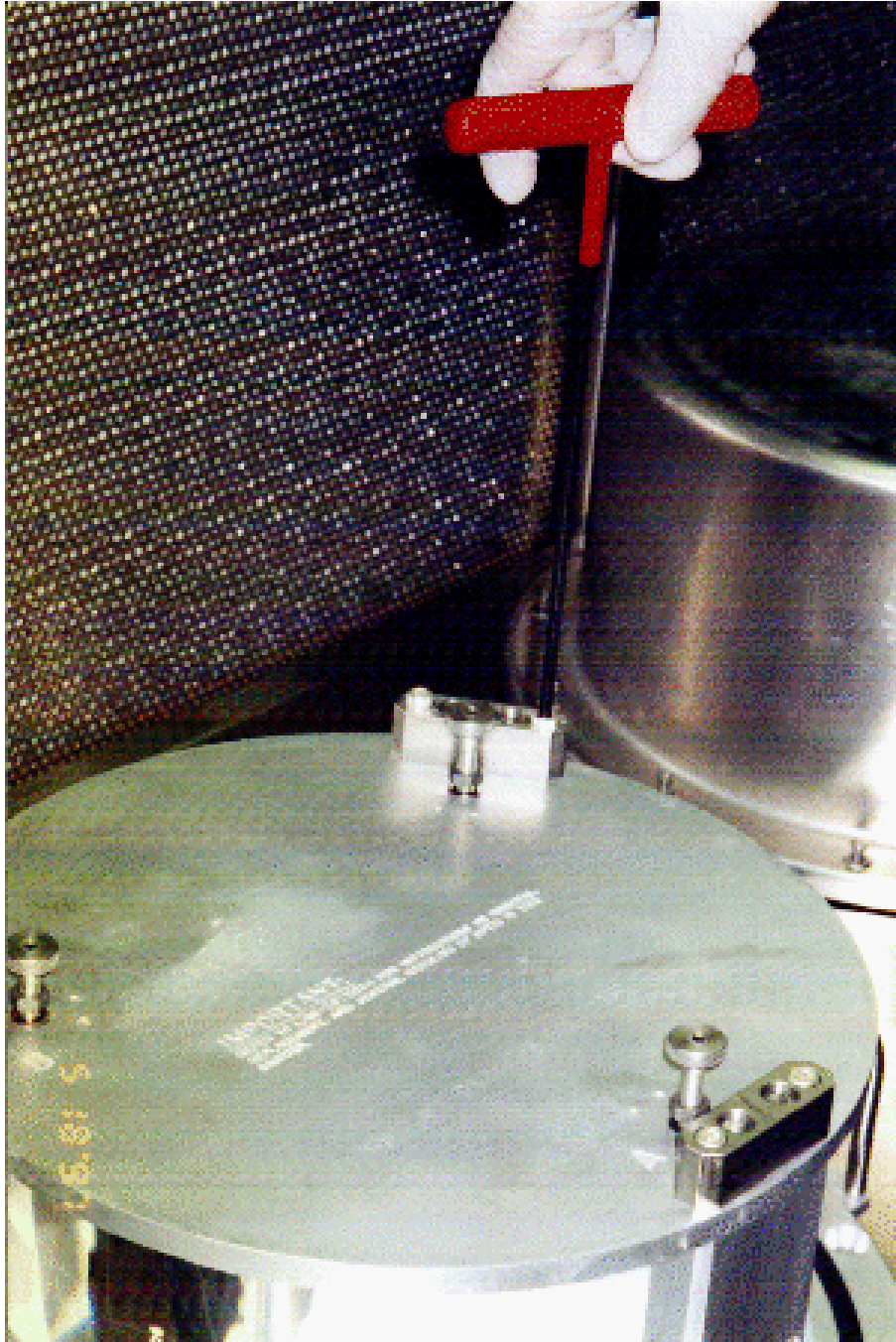
**Figure 8: Unloading the Teflon Side Pad on the Hinged Upright**



**Figure 9: Loosening Hex Nuts to Unlock the Top Plate Thumb Screws**

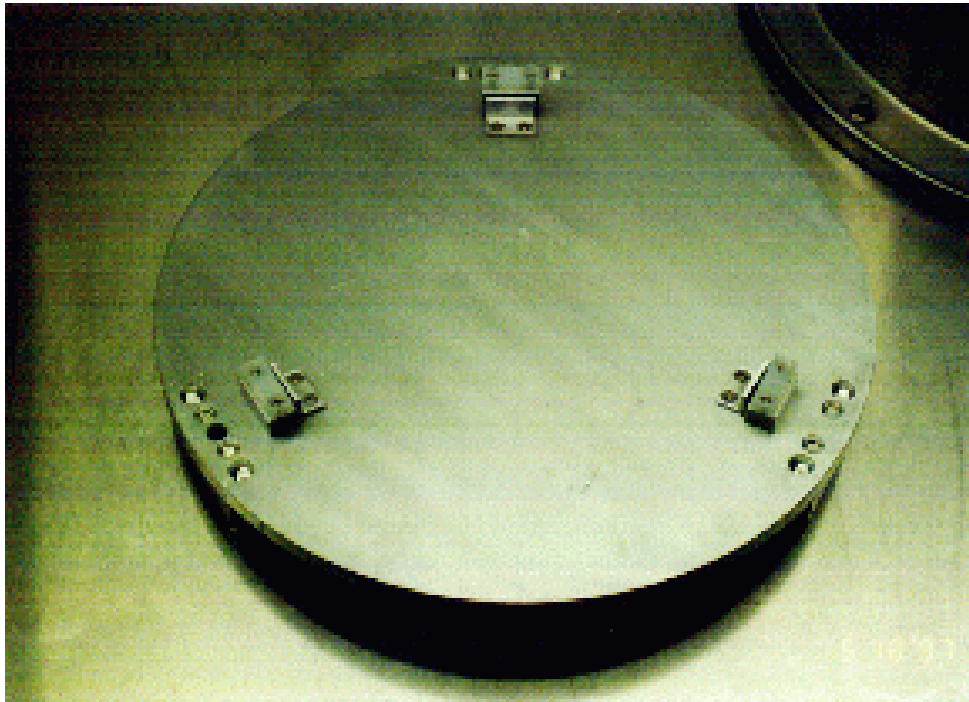
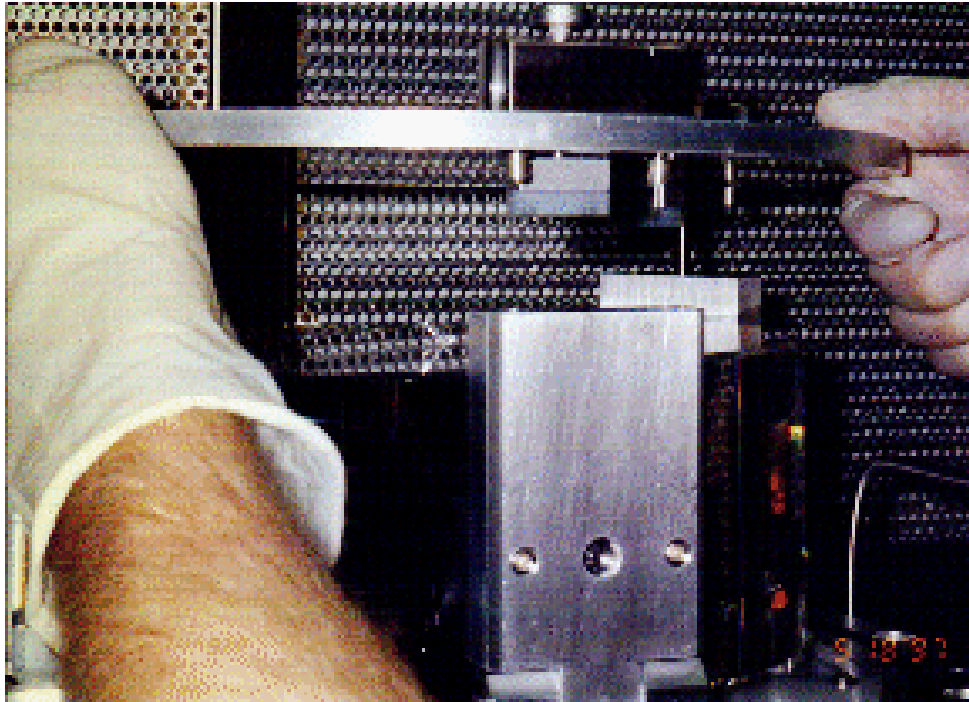
Using a 7/16" (11 mm) box wrench, loosen the hex nuts on the three top plate thumb screws (Figure 9). Back off the thumb screws lifting the teflon pads off of the optic's upper face.



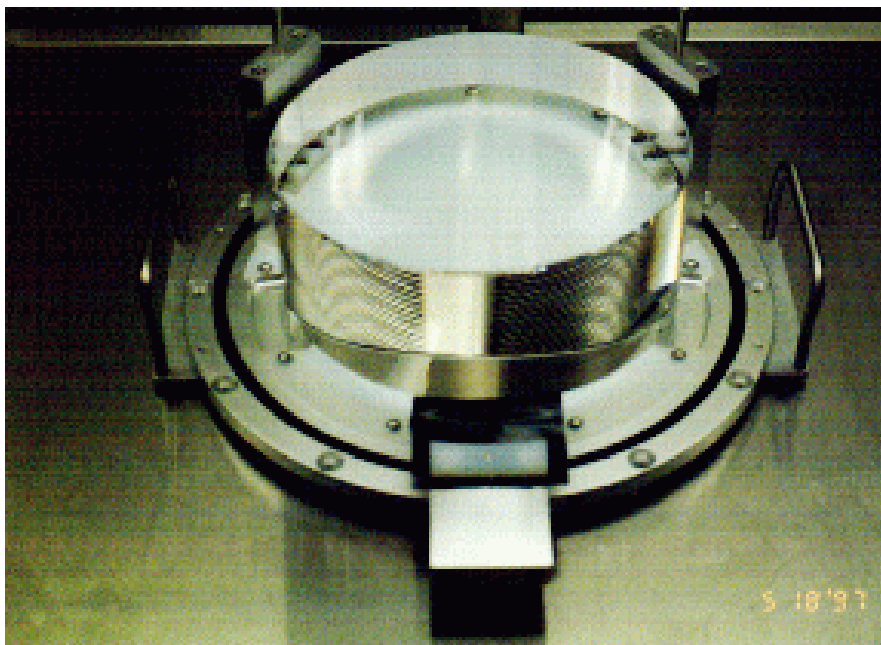


**Figure 10: Disengaging the Top Plate**

Using a 3/16" (5 mm) hex key, disengage the six socketed captive screws which fasten the top plate to the carrier body (Figure 10). Remove the top plate and place upside down on a clean flow bench surface (Figures 11 & 12). Always avoid any contact to the teflon pad surfaces. Do not place the lid over the top plate as this could cause accidental damage. Polyester cleanwipes may be placed over each teflon pad for protection.



**Figures 11 & 12: Removing the Top Plate**



**Figure 13: Upright Member Folded Down**

Fold down the hinged upright member (Figure 13). Before removing the optic, make sure the destination path is clear. Lift the optic out using the special handle clamp (not shown) provided by LIGO.

## 2.4. Laboratory Processing of the Core Optic Component

All processing of optics shall be according to pertinent and current LIGO specifications for the particular processes.

**Table 1: Core Optic Component Processing Documents**

| <i>Title</i>                                            | <i>Document no.</i> |
|---------------------------------------------------------|---------------------|
| Cleaning                                                | LIGO-E9xxxxx (TBD)  |
| Polishing Specification for Substrate, Recycling Mirror | LIGO-E960092        |
| Polishing Specification for Substrate, Input Test Mass  | LIGO-E960093        |
| Polishing Specification for Substrate, Beam Splitter    | LIGO-E960100        |
| Polishing Specification for Substrate, Folding Mirror   | LIGO-E960101        |
| Polishing Specification for Substrate, End Test Mass    | LIGO-E960102        |

**Table 1: Core Optic Component Processing Documents**

| <i>Title</i>                                                       | <i>Document no.</i> |
|--------------------------------------------------------------------|---------------------|
| Polishing Specification for Substrate, Superpolished End Test Mass | LIGO-E960104        |
|                                                                    |                     |
| Metrology                                                          | LIGO-T000129        |
|                                                                    |                     |
| Coating Specification for SPETM01-A                                | LIGO-E980068        |
| Coating Specification for SPETM02-A                                | LIGO-E980068        |
| Coating Specification for SPETM03-A                                | LIGO-E980068        |
| Coating Specification for SPETM04-A                                | LIGO-E980068        |
| Coating Specification for SPETM05-A                                | LIGO-E980068        |
| Coating Specification for SPETM06-A                                | LIGO-E980068        |
| Coating Specification for SPETM07-A                                | LIGO-E980068        |
|                                                                    |                     |
| Coating Specification for ETM01-A                                  | LIGO-E980068        |
| Coating Specification for ETM02-A                                  | LIGO-E980068        |
| Coating Specification for ETM03-A                                  | LIGO-E980068        |
| Coating Specification for ETM04-A                                  | LIGO-E980068        |
|                                                                    |                     |
| Coating Specification for FM01-A                                   | LIGO-E980065        |
| Coating Specification for FM02-A                                   | LIGO-E980065        |
| Coating Specification for FM03-A                                   | LIGO-E980065        |
| Coating Specification for FM04-A                                   | LIGO-E980065        |
|                                                                    |                     |
| Coating Specification for RM01-A                                   | LIGO-E980070        |
| Coating Specification for RM02-A                                   | LIGO-E980070        |
| Coating Specification for RM03-A                                   | LIGO-E980070        |
| Coating Specification for RM04-A                                   | LIGO-E980070        |

Optics shall be cleaned per LIGO-TBD during processing whenever possibly hazardous contamination occurs. After all processing is complete, optics shall be cleaned per LIGO-TBD and placed in their carriers.

## 2.5. Replacement of the Core Optic Component Into the Carrier

**Note:** Minimize travel of the optic when unprotected. The optic shall not be moved more than ten feet (3 m) when outside of the carrier. Always plan for minimized motion before replacing optics into carriers.



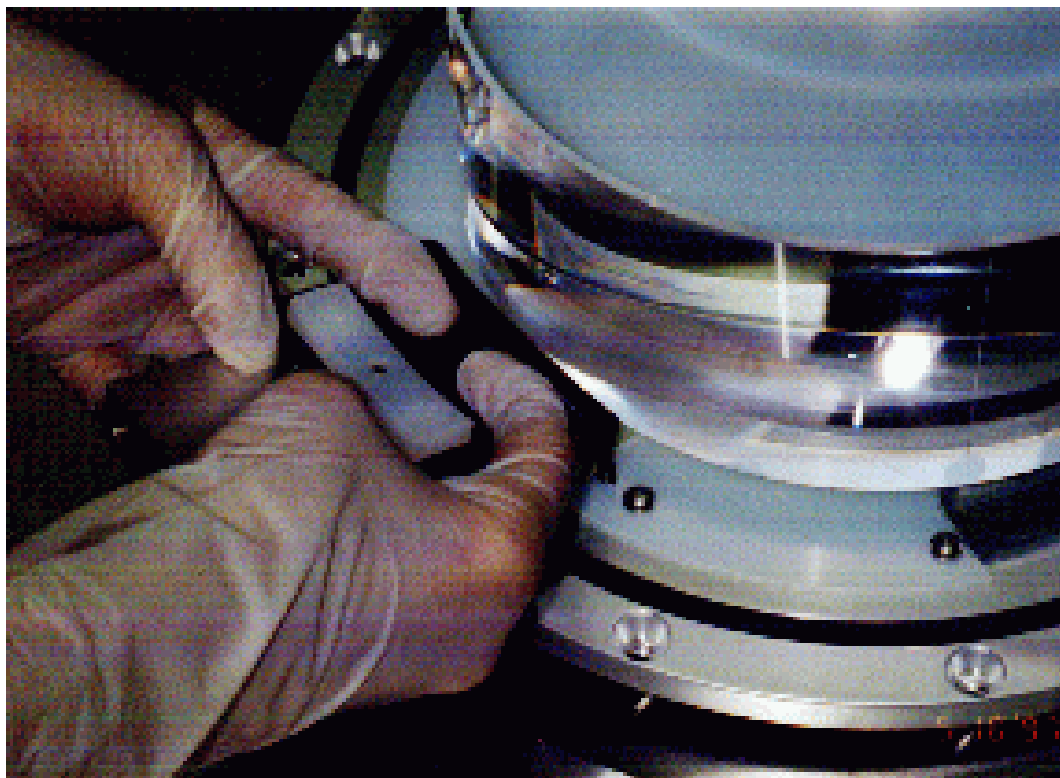
**Figure 14: Optic Being Placed In the Carrier**

Before placing the optic into the carrier, wipe all surfaces of the carrier with a clean-room grade lint free polyester cloth (cleanwipe). Subsequently wipe all contact faces of the teflon pads carefully with new cleanwipes. Using the special handle clamp (not shown) provided by LIGO, the optic must be placed into the carrier atop the three teflon base pads, with the registration arrow on the optic pointing down and clocked to the index mark on the left stationary upright member of the carrier as shown in Figure 14 (method shown, gripping optic with hands, is obsolete). Push the optic snugly against the two side pads on the stationary upright members.

Swing upward the hinged upright member as shown using forefingers to cause the protective viton sheets to properly fold without impinging between the teflon side pad and the optic's cylindrical face (Figure 15).

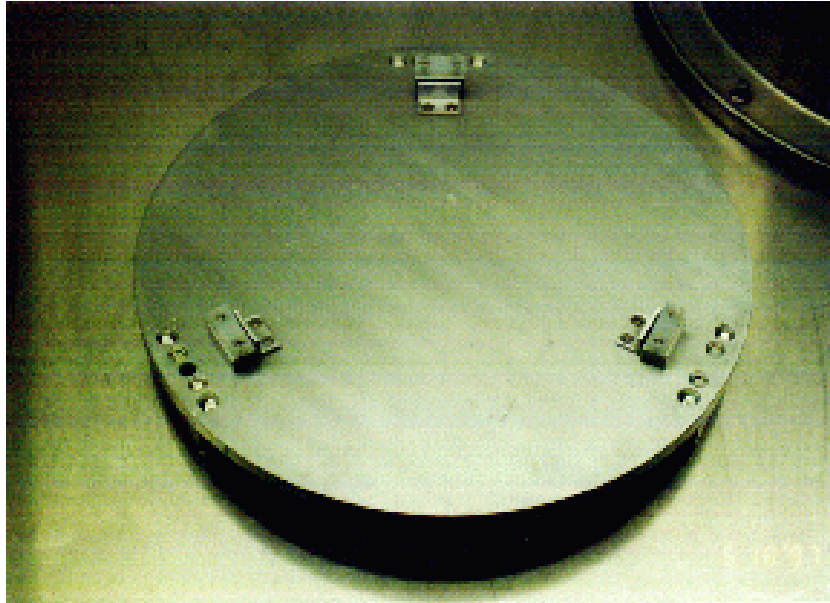
**Note:** When originally placing an optic into a carrier, the three carrier side pads must be fit to the optic immediately after setting the optic into the carrier. Center the optic by eye giving it uniform spacing from the three side pads (make sure the side pads are not adjusted forward). The side pad on the hinged upright member should be approximately 1/16" (1.5 mm) closer to the

optic than the other two side pads to compensate for the thickness of the viton. These spacings will be somewhat subjective for double wedged optics. Once the optic is centered, adjust the two side pads on the stationary upright members to just touch the optic snugly without moving it from its centered position.

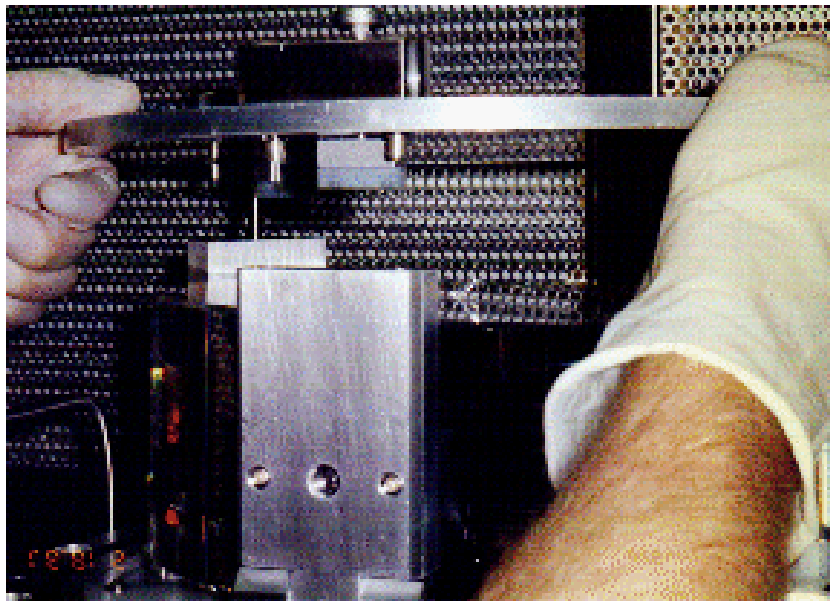


**Figure 15: Folding the Hinged Upright Upward**

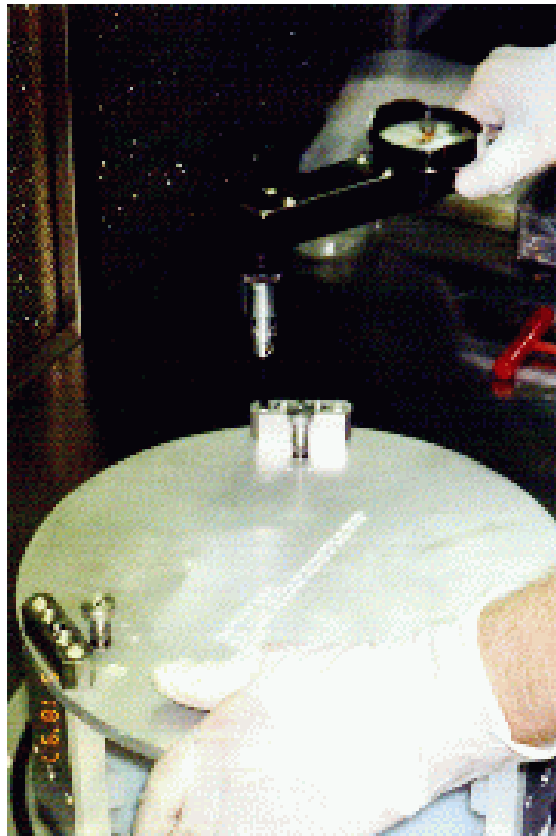
Before replacing top plate, wipe all surfaces with a clean-room grade lint free polyester cloth (cleanwipe). Subsequently, wipe the contact faces of the three teflon pads carefully with new cleanwipes (Figure 16). Place the top plate in position taking caution not to strike the teflon pads on the upright members. Notice the two locating holes which match the two dowel pins on the stationary upright members (Figure 17). Torque the six socketed captive screws to 70 in-lb (8.0 N-m) using a 3/16" (5 mm) hex key (Figure 18). Tighten the side pad set screws in the hinged upright member using a 1/8" (3 mm) hex key until they are well snugged about the optic (the side pads will bend around the optic's cylindrical face to conform, Figure 19). Tighten the three top plate thumb screws until they are firmly seated, then lock them by tightening the hex nuts against the upper surface of the top plate while holding the thumb screw in place. Use a 7/16" (11 mm) box wrench (Figure 20). Wipe the cover with a clean-room grade lint free polyester cloth. Place it over the carrier and fasten the 12 quarter turn locks (Figure 21).



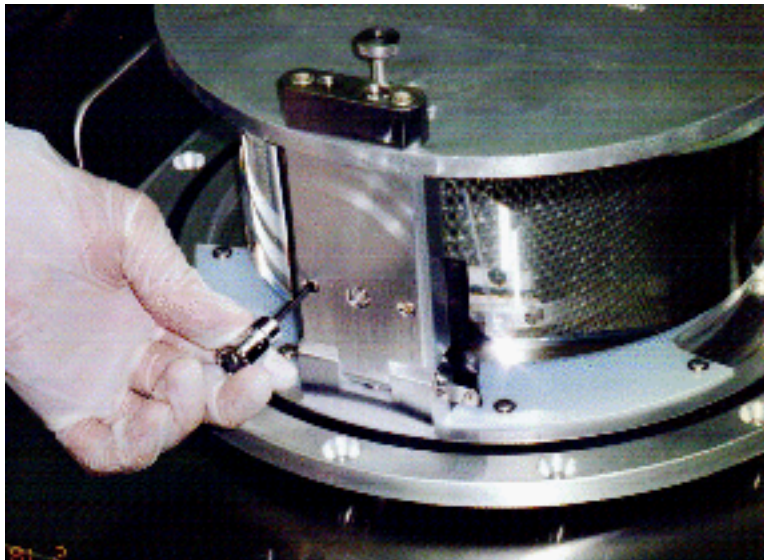
**Figure 16: Top Plate**



**Figure 17: Positioning the Top Plate**

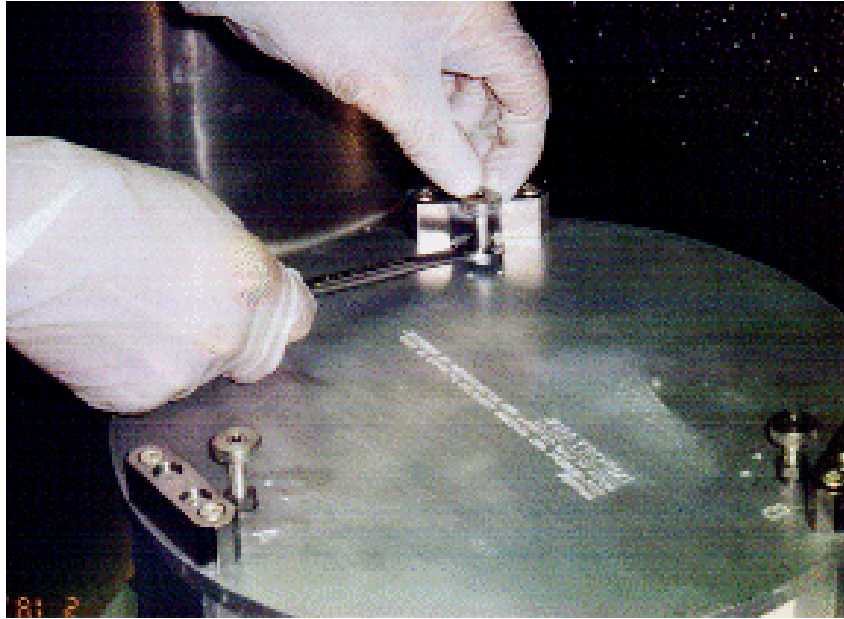


**Figure 18: Torquing the Top Plate To the Carrier Body**



**Figure 19: Tightening the Side Pad On the Hinged Upright**



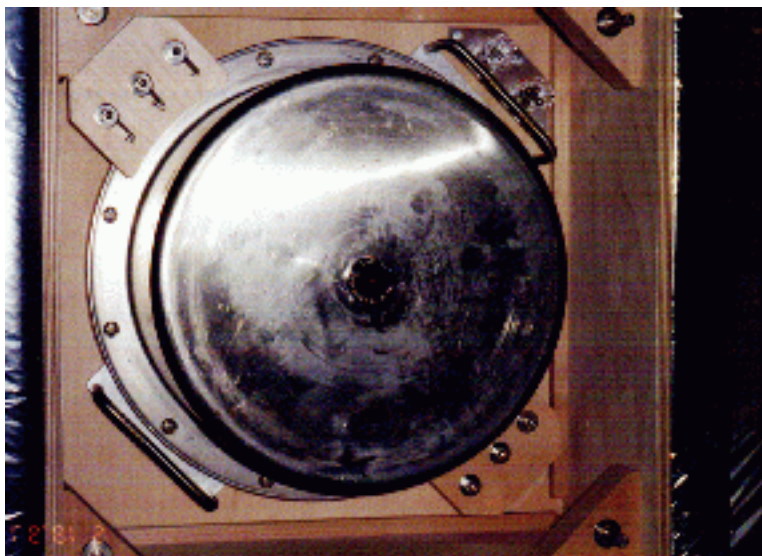


**Figure 20: Locking the Top Plate Thumb Screws**



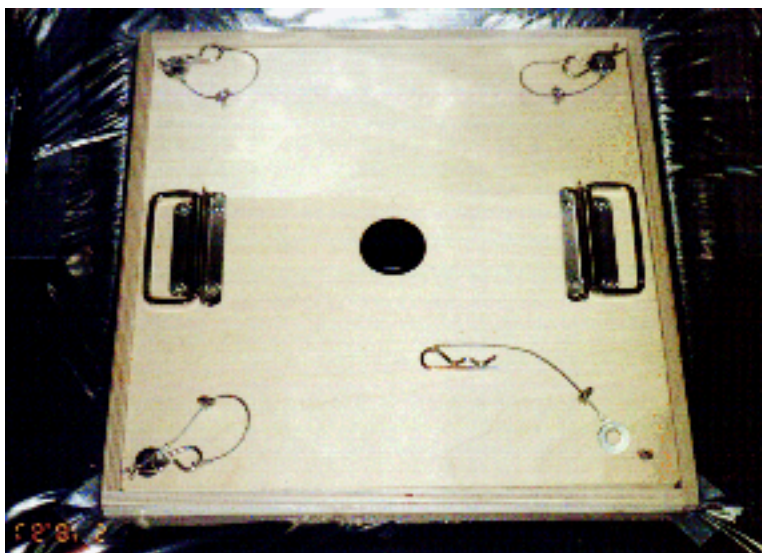
**Figure 21: Cover In Place**

## 2.6. Repackaging the Carrier



**Figure 22: Carrier Fixed In the Shipping Container's Compartment**

To secure the carrier in the shipping container, loosen the three socket screws on each hold-down clamp in the wooden compartment a few turns. Slide the slotted hold down clamp all the way back away from the center of the compartment. Slide the lip of the carrier base under the stationary hold-down clamp and set flat on the bottom of the compartment. Push the carrier snug into the stationary hold-down clamp, then slide the slotted hold-down clamp up snug against the lip of the carrier base (Figure 22). Tighten the 6 hold-down clamp screws using a 3/16" (5 mm) hex key.



**Figure 23: Fastening the Compartment Lid In Place**

After making sure that the two shock indicators are intact, place the plywood lid over the compartment and secure it by placing the tethered washers over each clevis pin and sliding the tethered clip pins through the clevis pin holes while pressing down on the corner of the compartment lid (Figure 23).

**Note:** For best results, apply the clip pins in round-about order. The last pin is typically difficult to engage unless using the following method:

Hold the washer in place over the clevis pin using a T-handled hex key. By bearing with ones weight to press down on the washer with the end of the hex key, the plywood lid can be pressed down to allow engagement of the clip pin using the other hand.



**Figure 24: Shipping Container Closed**

Close and latch the shipping container lid (Figure 24).

## 2.7. Shipping

Manual transporting of shipping containers containing optics shall be performed carefully, by two persons at all times. Before loading of shipping containers onto vehicle for shipping, make a note of any damages to exteriors of containers and file in a shipping and receiving log.

## 2.8. Storage

Optics are to be stored, whether for long or short periods of time, within their carriers, separate from shipping containers, in a clean-room environment. Before storing optics, they shall be cleaned per **LIGO-(TBD)** and placed in their carriers (see section 2.5., pp. 13-17).

**Note:** If optics are to be stored directly after receipt from shipping (except when shipped locally), they shall be unpackaged, removed from their carriers, and cleaned per **LIGO-(TBD)** before storing.