LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T080245-02-D | ADVANCED LIGO | 2 October 2008

ALIGO NP-type: - Report on bonding Viton stops, magnet holders and break-off prisms at LASTI

M. van Veggel[1], L. Cunningham[1], H. Armandula[2], R. Jones[1], M. Barton[2], J. O'Dell[3], K. Strain[1], M. Meyer[2], N. Robertson[2]

[1] Institute for Gravitational Research, University of Glasgow

[2] California Institute of Technology, LIGO Project

[3] Rutherford Appleton Laboratory

Distribution of this document:
LIGO Science Collaboration.
This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Institute for Gravitational Research

University of Glasgow
Kelvin Building
Glasgow G12 8QQ
Phone: +44 (0)141 330 3340
Fax: +44 (0)141 330 6833
Web: www.physics.gla.ac.uk/igr/

Massachusetts Institute of Technology
LIGO Project – NW22-295
185 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu

Rev 00	*23rd September 2008*	*First draft of report for comment (M. Van Veggel, W.Cunningham, Armandula*
Rev 01	*25th September 2008*	*Updated document with information from the coating vendor (M. van Veggel, W.Cunningham, H. Armandula)*
Rev 02	*2nd October 2008*	*Minor corrections to remove inconsistencies based on comments by N. Robertson (M. van Veggel)*

Introduction

From the 16th till the 19th of September 2008 the fourth and final bonding exercise was done at LASTI in preparation for welding in fibers and suspending the NP-type masses as part of the ALIGO ETM/ITM noise prototype activity. This exercise involved glueing steel break-offs to the Compensator Plate (CP), glueing Viton earthquake stops to the CP, glueing steel rings to the magnet flags and glueing magnet bases to the 2nd Penultimate Mass (2nd PM).

Preceding bonding exercises were done from 27th – 31st August 2007, 10th – 15th December 2007 and 11th – 17th February 2008 during which ears were bonded to the penultimate masses and the test mass. Reports of these exercises have references T070223-00-D and T070305-00-D, T080041-01-K.

This document reports on this 4th exercise.

1 Reference documents

Design documentation 'glass' essentials	
D050421-05-K	NP- type ETM Penultimate Mass
D060534-00-B	NP-type Thermal Compensator Plate
D040431-00-C	NP-type ETM Silica Test Mass
Design documentation 'non-glass' essentials	
D070033-02-D	NP-type Compensator Plate Wire Break-off Prism
D070234-00-K	Penultimate Reaction mass Magnets
D070237-03-K	Penultimate Reaction mass Magnet Base
D080241-00	Compensator Plate Viton stops
Design documentation of the alignment jigs	
D080467-00-D	CP Prism Bonding jig
D080406-00-D	CP Prism Bonding Fixture
D080407-00-D	CP Prism Holder
Measurement reports on 'glass' essentials	
GNL-4025-R1	Penultimate mass 1 measurements
GNL-4027-R2	Penultimate mass 2 measurements
Cleaning and Vacseal bonding procedures	
E960022-B	LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures
E970154-00-D	Large optics suspension balancing: component specification
E990035-C	Large Optics and COC's Cleaning Procedures
Other back ground documents	
T070223-00-K	ALIGO NP-type: - Report on Ear Bonding at LASTI 27th August – 31st August
T070305-00-D	ALIGO NP-type: - Report on Ear Bonding at LASTI 10th – 14th December 2007
T080041-01-K	ALIGO NP-type: - Report on Ear Bonding at LASTI 11th – 17th February 2008
T070138-00-K	Ribbon/Fiber Length Budget

2 Goals

Goals of the visit are to:

1) Glue earthquake stops to the Compensator Plate (CP)
2) Glue break-offs to the CP
3) Glue magnet inserts to the 2nd Penultimate Mass (PM)

3 Time schedule

Table 3.1 Expected (grey) and actual (black) time schedule

	Tue. 16-09-08		Wed. 17-09-08		Thu. 18-09-08		Fri. 19-09-08	
Preparations								
Glue break-offs to the CP plate								
Glue Viton stops to the CP								
Glue steel rings into the magnet flags and disc								
Glue magnet inserts to the PM								
Store masses								

4 Preparations

Fill in safety forms with David Schoemaker and Rich Mittleman. Main safety risk is the lifting of the masses. There are no chemical safety risks as the bonding solution is not hazardous. Vac Seal also poses minimal safety hazards.

All required items were accounted for except the magnets (check that tomorrow).

Set-up the clean room and clean equipment.

5 Observations on the Compensator Plate and bonding jig

5.1 Drawings

The compensator plate drawings as we had them were not complete (D060534). The drawings didn't have the information on the electrostatic drive coating and gold barrel coating. The only 'non-official information available on the coatings was through a CP and prism bonding jig assembly file for Solidworks provided by Michael Meyer (CP Prism Bonding Jig-3.easm). In the SWG teleconference on 16/09/2008, Michael Meyer was asked to update the drawings.

With respect to this file the electrostatic drive terminals have been applied with a 90 degree rotation, such that the drive terminals are on the sides. The latter way is how it should be and this was how the coating was applied.

5.2 Packaging

The CP was packed in a grey plastic container. The mass itself was in the multiplex wooden box, which was sitting in a foam container that was packed in Ameristat. The wooden box was not clean. The mass faces were covered Teflon face covers that were fitted over the edge of the barrel with a reasonably tight fit. The Teflon covers were not clean. The mass was stored in a plastic bag. The mass was prevented from moving around with foam padding.

The packing of the mass was much cheaper than the packing of the Input Test Mass, and with the wooden box, much better than the packing of the penultimate masses. The wooden box was equipped with a ledge, to ease lifting the mass out.

Before packing the CP back into the packaging the Teflon face covers were cleaned with methanol and blown dry with nitrogen. Around the perimeter of the face covers UHV aluminium foil was applied to protect the barrel and was sealed with Kapton tape. The wooden box was cleaned out as well as possible.

5.3 Inspection of the compensator plate

Inspection of the CP revealed the following flaws:

1. The electrostatic drive coating was covered with shallow scratches (Figure 5.1). The functionality of the coating was NOT believed to be impaired. An inquiry was made with the vendor to find the reason for the scratches. The scratches were made during an effort to protect the electrostatic drive coating during coating the barrel with gold. The gold pattern on surface was RF sputtered with an underlayer of ~400 Å of inconel and 1 micron of gold with NO overcoat. The coating was hard.

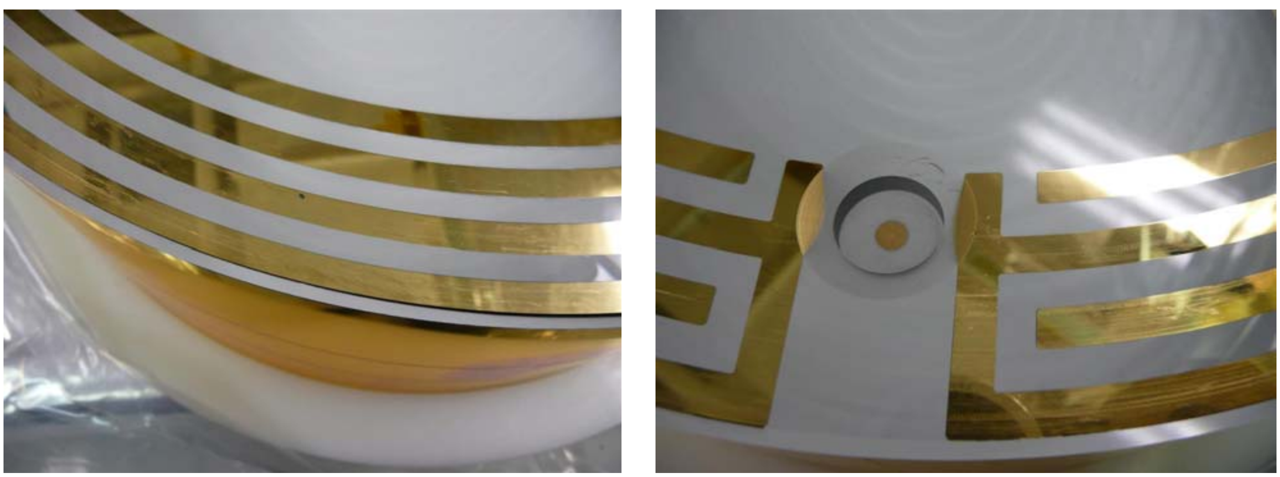


Figure 5.1 Shallow scratches on the electrostatic drive coating of the CP

The electrostatic drive coating also had an off-set from the centre towards the top of the mass, such that the coating went over the chamfer of the mass and came within a millimetre from the barrel coating (Figure 5.2).

Figure 5.2 Electrostatic drive coating over the chamfer, 1 mm away from the barrel coating

2. The barrel coating looked very uneven and on some locations the coating wiped off with methanol (Figure 5.3 left). The barrel was E-beam coated. It had the same underlayer of ~400 Å of inconel, 1000 Å = 100 nm of gold and an overcoat of Si + ~30 Å of a proprietary "binding" material.

   The tests plates coated with the part, according to the vendor, are very robust. The coater believes that the section that wiped off, had some sort of contamination and expects the rest to be OK. The coating is very thin with 100 nm, which means a lot of colour differences are visible (Figure 5.3 right). After discussion with the vendor it was decided to bond on the parts. If the coating is found to be flaking the CP will be sent back to the vendor for recoating.

wipe off marks **'finger print' marks**

Figure 5.3 Marks on the CP barrel coating

3. The fiducial lines on the sides of the CP were not made perpendicular to the front face of the mass. The deviation over the width of the mass (130 mm) is approximately 2 mm. The angular error is therefore 1.5 mrad or 0.9°. The fiducial lines matched up with the centres of the Viton stop holes near the front face. With the means available it was not possible to

determine the geometric centre of the CP. It was therefore assumed that the true geometric centre of the CP matched up with the fiducial line near the front (electrostatic drive) side of the CP.

As the CP does not have an accompanying inspection document, this flaw has not been detected before. It is recommended to perform size inspection measurements using a coordinate measuring machine or be present at the inspection measurements made at the vendor prior to delivery and define clearly what measurements must be taken.

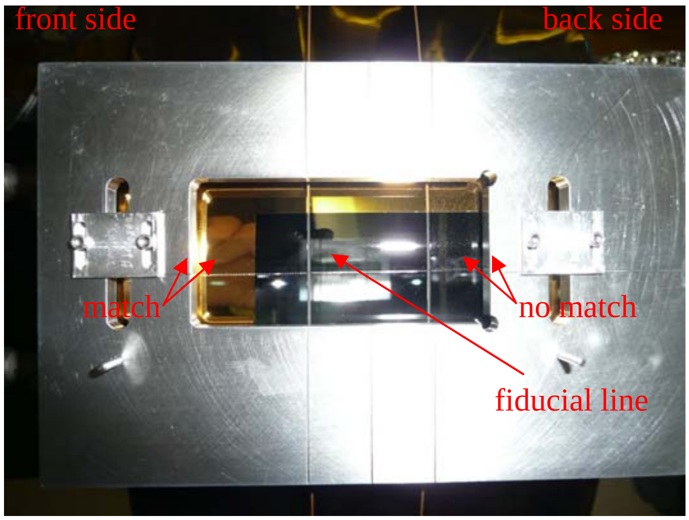


Figure 5.4 Fiducial line off-set

4. The mass was damage at the lower Viton stop inset counter bore. This problem was solved by the vendor by making a 5 mm chamfer on the hole to remove most of the damage. A small amount of damage was still visible (see right hand picture in Figure 5.1).

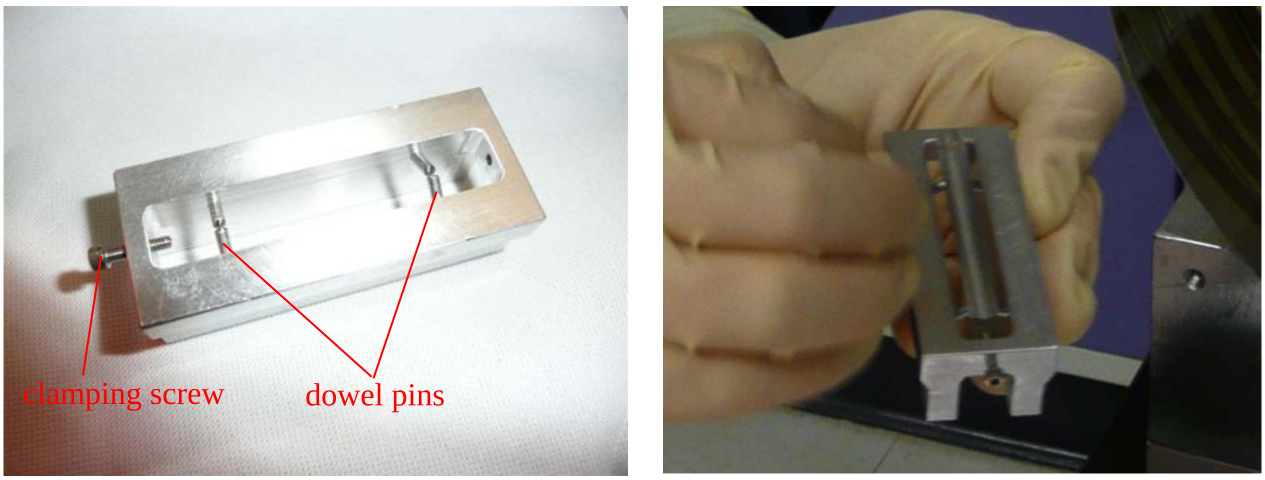
6 Adhesive (Vacseal bonding) and cleaning

6.1 Break-offs to the Compensator Plate

Procedure:

1. On 16/09/2008 the CP was moved onto the bonding table by lifting the mass holding the lower Teflon face cover. The mass is significantly lighter than the other masses, which means it can be lifted by one person.
2. The templates were set according to the measurements in section 6.2.
3. The mass was put vertically on a V-block again by lifting and tilting it using the lower Teflon face cover.
4. Because of the fragility of the barrel coating it was decided only to clean the prism bonding parts (not coated with gold) using an optical cloth wetted with methanol and gently blow the surface with filtered nitrogen dispensed from a deionizing gun.
5. Cleaned the copper wire with methanol

6. Cleaned the break-off prism for side 1 with methanol and blow dry it with the de-ionizing nitrogen gun
7. Applied the template to side 1, matching the fiducial line closest to the front with the jig as shown in figure 5.4.
8. Put the break-off prism for side 1 in the prism holder. The prism holder had been made with dowel pins that were pushed very close to each other (figure 6.1 left). This meant that the clamping screw was holding the prism very close to its narrow top and we had to be very careful that the prism would fall out of the prism holder. It is recommended to replace the dowel pins with small screws in the design of the prism holder to make it easier to assemble. Dowel pins require a lot of force which reduce the controllability when assembling. Also the pins should not be protruding as far, so that the prism can be held more comfortably.



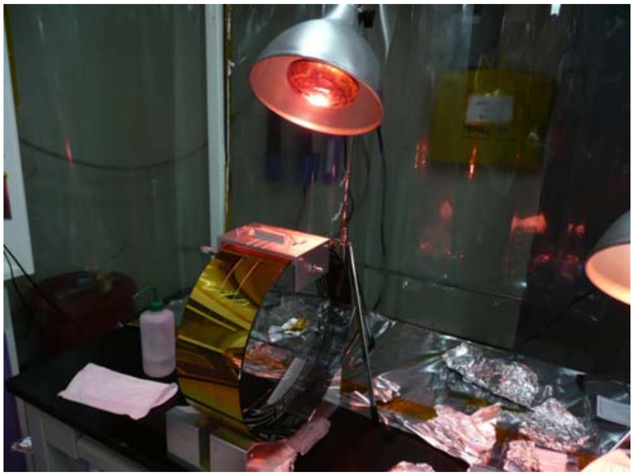
Prism holder **Prism holder with prism and applying adhesive**

Figure 6.1 Prism holder

9. Prepared the VacSeal (mix the two components in the package, apply the VacSeal in a UHV aluminum boat, put the VacSeal in the backing vacuum chamber to reduce the number of bubbles).
10. Checked both bonding surfaces for dust
11. Dipped the 0.3 mm copper wire in the VacSeal and apply a thin and even layer on the both contact surfaces of the break-off prism.
12. Glued the break-off prism to the CP by using the alignment jig.
13. Turned on the heat lamps and cured under the heat lamp overnight. Adhesive contact was made over the entire length of the prism on both bonding surfaces. Very little excess adhesive was observed (Figure 6.2).

bonded prism (side 1)

contact lines (side 1)



Adhesive curing on side 1

Figure 6.2 Bonding prism on side 1

14. Using the ergo arm the mass was turned over on 17/09/2008.
15. Set the bonding template for bonding on side 2 (upside down)
16. Wipe the bonding surface on side 2 with an optical cloth wetted with methanol
17. Cleaned the copper wire with methanol
18. Cleaned the break-off prism for side 2 with methanol
19. Applied the template to side 2 (upside down)
20. Put the break-off prism for side 2 in its template.
21. Checked both bonding surfaces for dust
22. Prepared the VacSeal
23. Dipped the 0.3 mm copper wire in the Vacseal and apply a thin and even layer on the both contact surfaces of the break-off prism.
24. Glued the break-off prism to the CP by using the alignment jig

25. Turn on the heat lamps and cure under the heat lamp overnight. Adhesive contact was made over the entire length of the prism and no excess adhesive was observed.

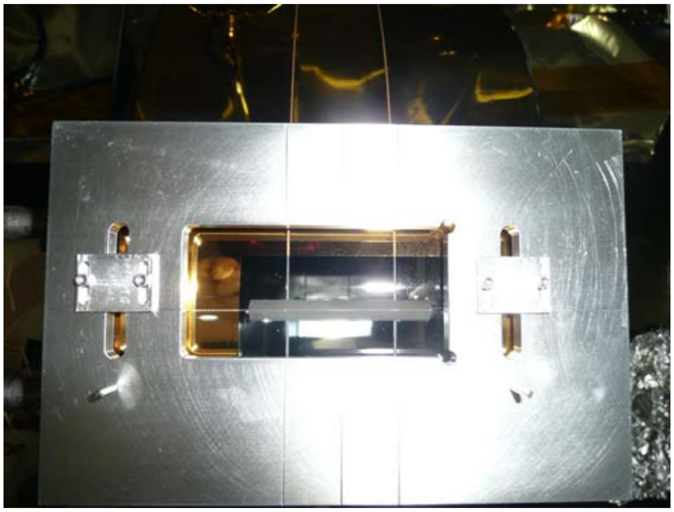


Figure 6.3 Bonded prism side 2

6.2 Template settings

- The template for the CP is shown in Figure 6.6. The following distances need to be set for the CP: D_{screw}, d_{slider}. There are two mirrored templates for the two sides.
- d_{slider} sets the vertical distance d_{prism} of the prism grooves to the centre of mass.

  $d_{prism} = d_{jig\ prism} - d_{slider}$

  As drawn in Figure 6.6 $d_{prism} = 0$ since $d_{jig\ prism} = d_{slider}$. If d_{slider} is smaller than $d_{jig\ prism}$, the prism is above the COM.

  In an e-mail communication with Mark Barton on 16/09/2008 (see appendix) d_{prism} = -0.57 mm from the COM. Due to the wedge of the mass the COM is 0.16 mm above the geometric centre line. As discussed in section 5.3 this geometric centre line has been assumed to be coincident with the fiducial line near the front (electrostatic drive) side of the mass.

  $d_{jig\ prism}$ was measured using a set of calipers: $d_{jig\ prism}$ = 18.8 mm (theoretically 19.0 mm)

  d_{prism} = -0.57 + 0.16 mm = -0.41 mm (16/09/2008)

  On side 1 the bonding jig was used the right way up leading to

  $d_{slider} = d_{jig\ prism} - d_{prism}$ = 18.8 + 0.41 mm = 19.2 mm

  On side 2 the bonding jig had to be used upside down leading to

  $d_{slider} = d_{jig\ prism} - d_{prism}$ = 18.8 - 0.41 mm = 18.4 mm

  It was expected that there were 2 mirrored bonding jigs present: one for each side. Since the same (non-wedged) surface needs to be referenced for both sides (especially in a wedged mass), the bonding jig had to be used upside down. This means one must be very careful to apply the jig to the correct side (know what is the top of the mass). This procedure was different in comparison to the other bonding exercises as we changed around the screws in those jigs, to be able to use the jig the right side up.

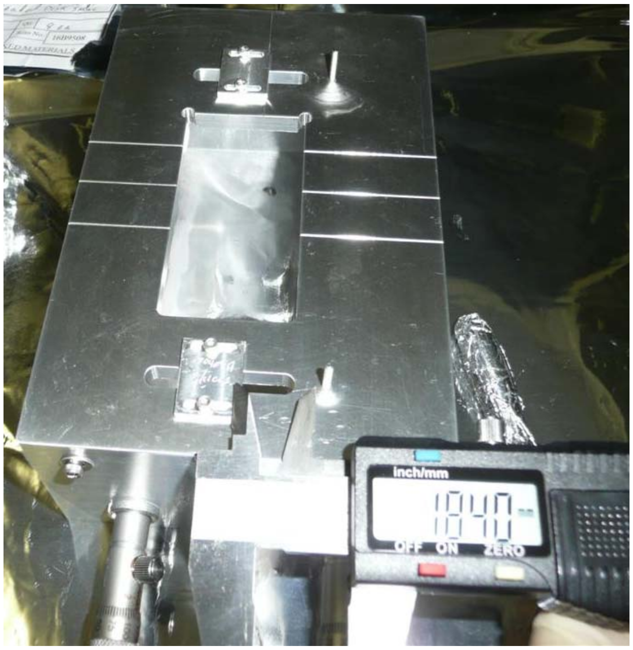


Figure 6.4 Setting prism bonding jig for side 2

- The theoretical $^1/_2$ width of the CP is $^1/_2 w_{CP}$ = 65.0 mm[1] around which the wire grooves are aligned symmetrically. The COM is according to D060534-B at $^1/_2 w_{CP}$ = 64.75 mm from the front (gold coated) surface. At the 28/08/08 fiber meeting it was decided to use $^1/_2 w_{CP}$ = 64.75 mm.

  Measured $w_{ref\ h}$ = 98.6 mm (theoretical $w_{ref\ h}$ = 98.5 mm)

  Measured $w_{prism\ ref}$ = $w_{prism\ h}$ = 28.5 mm (theoretical $w_{prism\ ref}$ = 28.5 mm),

  Measured w_{prism} = 50.0 mm (theoretical w_{prism} = 50.0 mm),

  Measured t_{holder} = 3.4 mm (theoretical t_{holder} = 3.5 mm),

  Actually set screw: $D_{screw} = w_{ref\ h} - {}^1/_2 w_{CP} - {}^1/_2 w_{prism} - t_{holder}$ = 5.45 mm (theoretical 5.25 mm). The set screws were set using slip gauges.

Table 6.1 Actually set bonding jig setup for the CP (16/09/2008)

	Side 1	**Side 2**
D-slider	19.2 mm	18.4 mm
D-screw	5.45 mm	5.45 mm

[1] D060534-B Drawing Thermal Compensator Plate

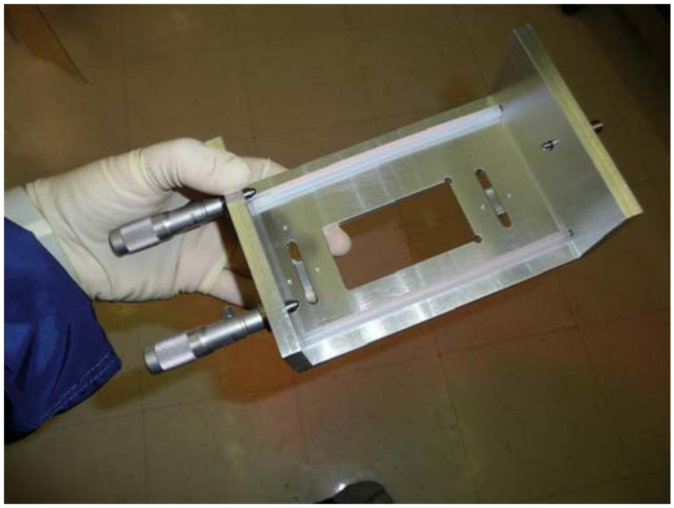


Figure 6.5 Underside of the bonding jig

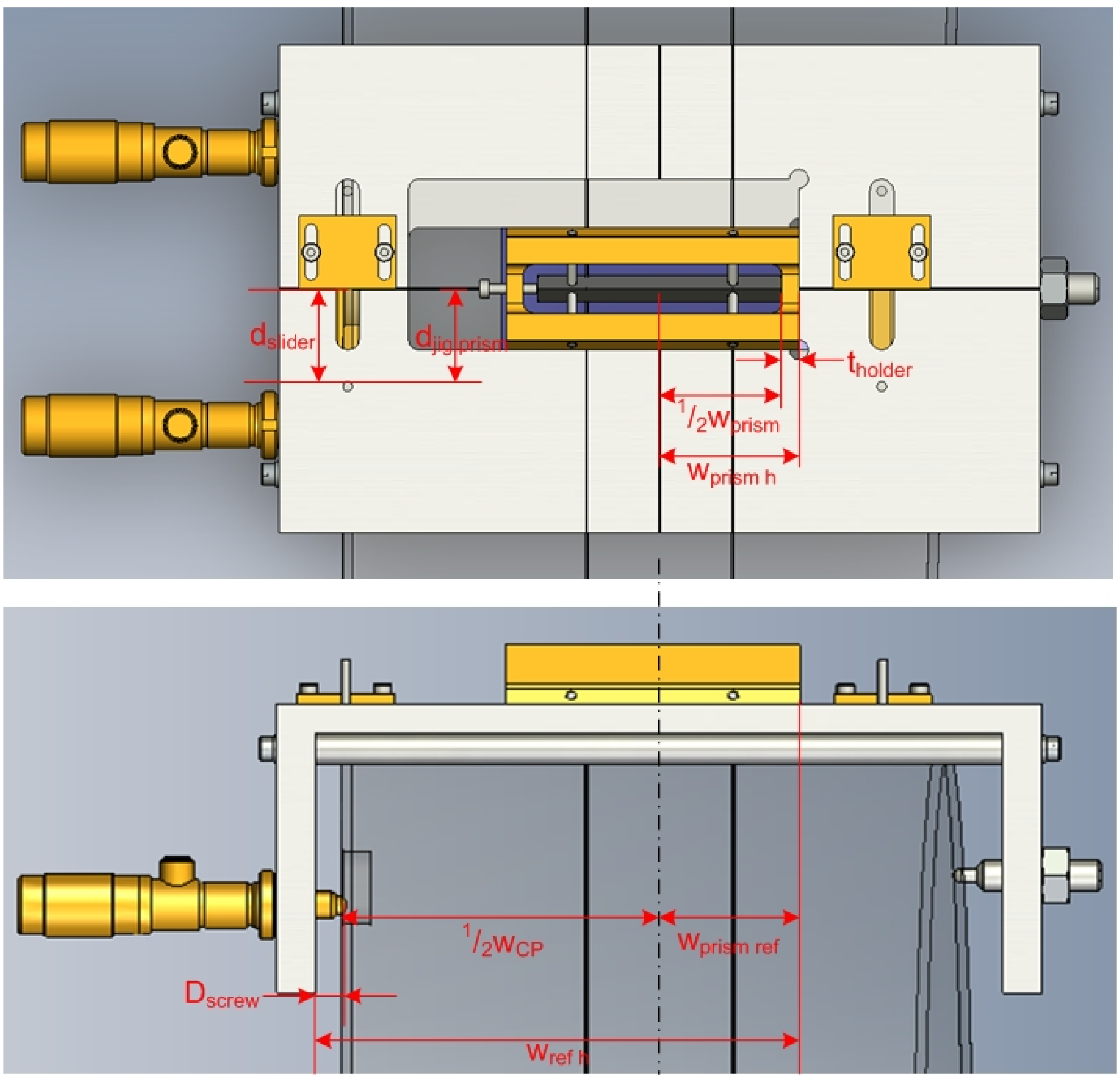


Figure 6.6 Bonding template for the compensator plate

6.3 Earthquake stops to the Compensator Plate

The Earthquake stops consist of 3 parts.

1. Fused silica tip: that serves as the direct contact between the test mass and the stop
2. The mount plate: a metallic disc with thread end
3. The Earthquake stop: a Viton rubber cylindrical piece that screws onto the mount plate

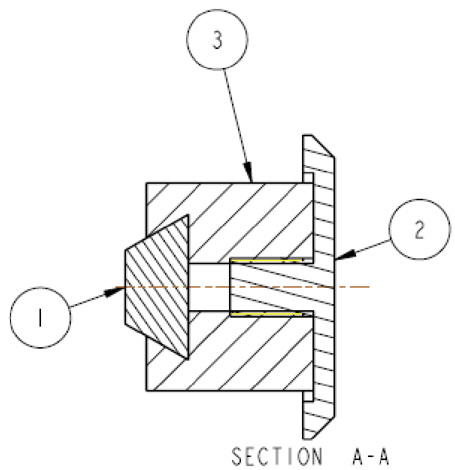


Figure 6.7 Viton stop cross-sectional drawing (D080241)

The mount plates were glued into the 4 counter bores in the CP according to the following procedure:

1. Using the cleaned Teflon face cover the CP was sat from the V-block onto its back surface.
2. Cleaned the mount plates stops with methanol and blow dry them with the de-ionizing nitrogen gun
3. Cleaned the copper wire with methanol
4. Prepared the VacSeal
5. Dipped the copper wire in the VacSeal
6. Apply the VacSeal to the mount plates (Figure 6.8 left)

Figure 6.8 Applying adhesive and bonding the mount plates for the Earthquake stops on the CP

7. Glued in the mount plates
8. Put the heat lamp on the surface and cure the adhesive overnight. Adhesion is good.
9. The mass was packed back into its container as discussed in section 5.2. The Viton earthquake stops were stored with the mass as was a cutter. The Viton stops will need to be cut to a shorter length just before assembly. Joe O'Dell mentioned a length of 8 mm in stead of the current 10 mm. This will however need to be checked prior to assembly. The silica tips are with Brett Shapiro. Assembly of the silica tips into the Viton stops is not trivial. Joe O'Dell mentioned on 16/09/2008 that a tool for that is in development.

6.4 Magnet assemblies for the 2nd Penultimate Mass

The magnet assemblies for the penultimate mass consist of 7 parts:

1. Magnet flag
2. (Mass)
3. Magnet base
4. 3x Steel disc
5. 2x Magnets

The steel rings serve as attraction base for the magnets and were to be glued into the magnet flags on both ends and into the magnet base (Figure 6.9).

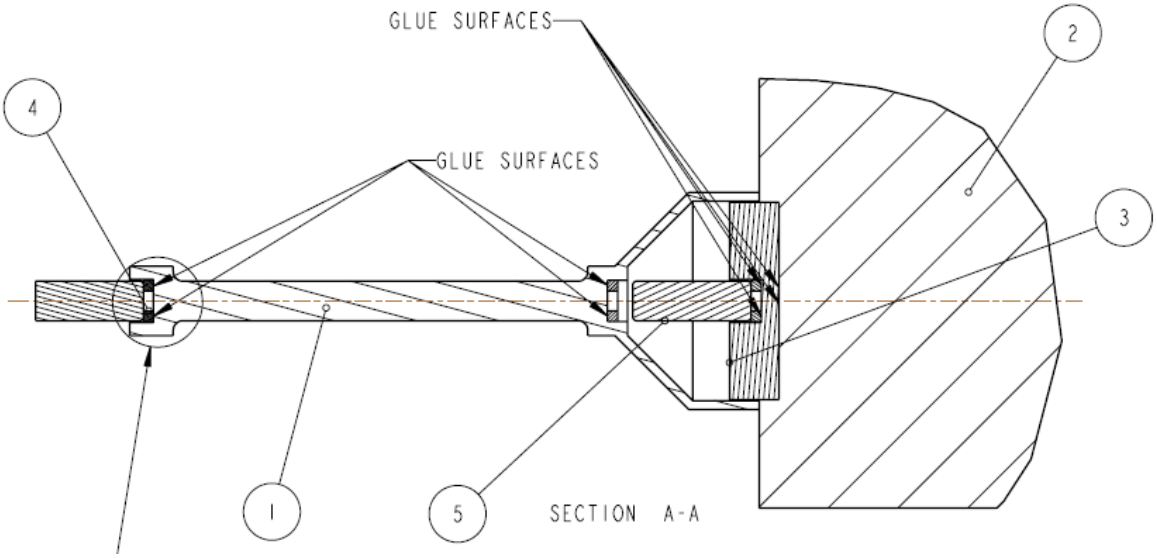


Figure 6.9 Cross-section of the magnet assembly

The magnet base with glued in steel ring then had to be glued into the shallow counter bores in the PM.

Procedure:

1. The steel rings, magnet based and magnet flags were wiped with methanol. A set of 8 magnet flags were prepared by glueing in the steel rings over 2 days.
2. Prepared VacSeal.
3. Dipped the copper wire in the VacSeal
4. Picked up the steel rings with a pair of tweezers and applied the VacSeal to the back
5. Glued in the steel rings
6. A heat lamp was used to cure the adhesive overnight. No excess adhesive protruded at the front to prevent the magnets from properly adhering to the steel rings.

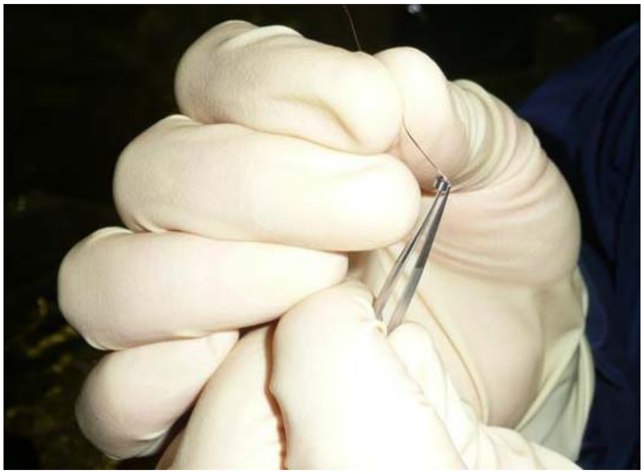


Figure 6.10 Glueing steel rings into the magnet flags

7. The counter bores were faced down in the container. Therefore the 2nd PM was lifted out of the container using the ergo-arm, put on a V-block and put back into the container using the ergo-arm again with the magnet counter bores up.
8. The surface was wiped with an optical cloth wetted with methanol and the counter bores were thoroughly wiped with methanol to get rid of dust.
9. Cleaned the magnet insets with methanol
10. Cleaned the copper wire with methanol
11. Prepared the VacSeal
12. Dip the copper wire in the VacSeal
13. The magnet bases were held using a pair of tweezers and the VacSeal to the back using the copper wire
14. Glued in the magnet bases
15. Put the heat lamp on the surface and cure the adhesive overnight
16. The mass was packed again and the assembled magnet flags were stored with it, including the spares. The only items missing were the magnets themselves. Amanda Brummit will order them and have them sent to LASTI.

Applying adhesive

Glueing magnet base

Curing

Figure 6.11 Bonding magnet bases to the 2nd PM

7 Conclusions and recommendations

The drawings for the CP were incomplete and no inspection documents for the CP were available. This is owed to the fact that the mass was procured at a rush, which probably led to reduced quality in the mass and the coatings.

The following observations were made on the CP:

1. The electrostatic drive coating was damaged with shallow scratches. The scratches are unlikely to affect its functionality.
2. The electrostatic drive coating is off-set from the COM with the coating coming within 1 mm from the barrel coating at the top.
3. The barrel coating is very soft and fragile and shows scratches, wipe marks and finger marks.

4. The fiducial lines on the sides have not been applied perpendicular to the front face of the mass.

It is recommended to always fully finish all drawings before manufacture of the silica masses.

It is also recommended to ask the vendor to supply an inspection document with measurements of crucial parts of the mass as specified by LIGO. Preferably LIGO personal should be present at the inspection measurements. Alternatively, inspection of all silica masses could be done within LIGO using a coordinate measuring machine with an accuracy of ±10 μm. The measurement of the position of the fiducial lines should be incorporated in the inspection.

The prisms have been bonded on successfully. Their position has been based on the assumption that the position of the fiducial lines near the front (electrostatic drive) side matches up with the COM.

The CP prism bonding jig worked properly. It is recommended though to replace the dowel pins in the design of the prism holder with screws to make assembly easier and more controlled.

The mount plates of the Earthquake stops were glued into the CP successfully. The Viton earthquake stops were stored with the CP. A cutter was also stored with the CP. The Viton stops will need to be cut to a shorter length just before assembly. Joe O'Dell mentioned a length of 8 mm in stead of the current 10 mm. This will however need to be checked prior to assembly. The silica tips are with Brett Shapiro. Assembly of the silica tips into the viton stops is not trivial. Joe O'Dell mentioned on 16/09/2008 that a tool for that is in development.

The steel rings were glued successfully into the magnet flags and magnet bases to make 8 flags (1 set for the 2nd PM and 1 spare set). The magnet bases were glued into the counter bores of the 2nd PM successfully. The 2nd PM was packed again and the assembled magnet flags were stored with it, including the spares. The only items missing were the magnets themselves. Amanda Brummit will order them (18/09/2008) and have them sent to LASTI.

Appendix 1: E-mail communication with Mark Barton 16/09/2008

```
Agreed - I ran the numbers through my Mathematica code as a double check and
+0.16 mm it is.

Cheers,

Mark B.
On Sep 16, 2008, at 11:53 AM, <m.veggel@physics.gla.ac.uk>
<m.veggel@physics.gla.ac.uk  > wrote:

> Hi Mark,
>
> The wedge according to the drawing I have is 10 arcmin = 0.17 degrees.
> This means the mass is 1 mm thicker at the top than it is at the
> bottom.
> This moves the COM up with 0.16 mm wrt the fiducial line.
> This leads to dPRISM = -0.57 + 0.16 = -0.41 mm.
> AGREED?????
>
> Cheers,
>
> Marielle
>
>
```

```
>
>> Hi,
>>
>>    Vertically, the flexure length is 0.00156595 m, i.e., 1.57 mm, so to
>> get an effective d4 = +1 mm, the breakoff point should be 1-1.57 mm =
>> -0.57 mm (i.e., below the COM). That of course is the COM, not the
>> scribe lines at 3 and 9 on the barrel. Since there's a very small
>> vertical wedge the COM will be slightly above the line. I haven't
>> calculated that offset but I can if you remind me of the value.
>>
>> And of course, the prisms should be placed symmetrically about the
>> COM position front to back, which will also be slightly offset
>> because of the wedge.
>>
>> Cheers,
>>
>> Mark B.
>>
>> ***********************************************
>> Dr. Mark Barton
>> LIGO Project
>> MC 18-34 Caltech
>> Pasadena CA 91125
>>
>> Tel:     +1 626 395 2973
>> Fax:     +1 504 285 2122
>> ***********************************************
```

Appendix 2: List of required items

Essentials

- Break-off prisms (2x SS314 prisms, plus spares) for the Compensator Plate.
- Masses (2nd penultimate mass, test mass, compensator plate, reaction mass)

Bonding Jigs

- 1 full bonding jigs for the penultimate masses is available for use (including templates, holders, t-pieces etc)
- 1 full bonding jig for the reaction mass is available for use
- Tools for setting up jig (Allen keys/wrench/tweezers)

Bonding equipment and consumables

- Flowing de-ionised water
- Methanol
- Deionising gun with pure, filtered nitrogen (low pressure)

Glueing equipment

- Perkin-Elmer Vac-Seal epoxy resin
- Backing pump
- Heat lamps on posts
- Copper wire
- Acetone
- Methanol

Large items

- Ergo arm and ring clamp
- V-blocks
- Vacuum oven
- 2 tables (one for set-up and one for bonding)

Measuring devices

- Plastic ruler
- Digital callipers
- Height gauge
- Metric Feeler gauges
- Metric Slip gauges

Other items

- Lighting: Osram LED work light
- Magnifying glass
- Clothing: Clean room suits, overshoes, gloves, hairnets, face covers
- First Contact™ surface polymer
- Crash mat: used below ergo arm when manipulating the mass in free space
- Photo camera
- UHV aluminium foil
- Ameristat