



*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO-E1000752-v4

**ADVANCED LIGO**

19<sup>th</sup> September 2012

Preparation of a thin compensator plate (TCP) or end  
reaction mass (ERM)

(Gluing wire break-off prisms and earthquake stops)

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# 1 Introduction

## 1.1 Purpose and Scope

This document goes through the procedure for preparing a Thin Compensator Plate (TCP) or End Reaction Mass (ERM) (D1000979 and D080116) for installation into the reaction chains of the quadruple suspension structure (end station for the ERM and input station for the TCP). The procedure consists of two steps:

- 1) Gluing the wire break-off prisms onto the (approximately) 9 and 3 o'clock positions of the barrel of the TCP or ERM.
- 2) Glue 4 earthquake stop attachment pieces to the face of the optic (on the side of the gold coated ESD pattern).

The procedure starts from the point the ERM or TCP has been delivered from all vendors and the necessary quality control of the masses has been conducted by aLIGO personnel.

The procedure ends with storing the mass awaiting inserting into the chain. It includes handling the mass using the ergo-arm (D1002605). Mirror handling procedures with the ergo-arm are detailed in T1000082 and T1000534. As the optic cannot be lifted up with the ergo-arm on the ESD side of the optic, but will need to be put down with the ESD facing up, also an inspection fixture (D1000812) will be used with which the optic can be lifted manually by two persons.

The ERM and TCP have a different width. Therefore the bonding jigs for the wire break-off prisms have a different width. The principle design of the jigs is the same though, therefore procedures are the same.

The required alignment accuracy for the prisms front to back (in horizontal direction) onto the barrels of the ERM and TCP w.r.t. the centre of mass is  $\pm 0.3$  mm (somewhat less tight than ears and prisms on the ETM and ITM, because the reaction chain has a larger tilt adjustment range than the main chain). This means that based on the quality documentation a unique serial number for each prism is not required. This has been confirmed by e-mail communication by Norna Robertson to Mariëlle van Veggel on 28/06/2010 and confirmed again in discussions at the technical meeting on 07/12/2010. All prisms have been produced with an accuracy of  $\pm 0.15$  mm. The average width of the mass has been specified in the drawings to be accurate within  $\pm 0.5$  mm. Because this is a larger value than the required  $\pm 0.3$  mm accuracy, the measured mean width of the mass will be used in the jig settings calculations. This takes into account the shift of the COM caused by the wedge angle of the mass as well. For jig setting calculations therefore the measured mean width of the mass divided by two will be used to calculate the distance of COM from surface S1 of the mass.

The ERM has circular recesses for the earthquake stops, where the TCP does not have those. The circular recesses on the ERM can be used to locate the earthquake stops as a base is glued into each one. The earthquake stops on the TCP can be located by the shape and location of the gold pattern for the ESD. Circular spaces have been left where the earthquake stop should be located. The required tolerance is not tight, which means that the stops can be located during gluing without the aid of a positioning jig. The TCP earthquake stop (D1003106) has a somewhat different design than the ERM earthquake stop (D080241). The design changes for the former with respect to the latter are discussed in T1000667.

It assumes that the mass has been stored in a COC CP storage container or ‘cake-tin’ (D0902001). In case of the TCP an adaptor (D1000958) is included in the storage assembly to make up for the smaller width. As of 10/12/2010 the TCP cannot be stored in the TCP storage container after gluing on the earthquake stop mount plates. Adaptations to the storage container will be made to make this possible.

Masterbond EP30-2 is the adhesive used to glue the prisms and earthquake stop bases. Guidance on the gluing procedure has evolved in response to lessons learned and the current reference is M1200294.

This procedure does not include the attachment of the ESD cables to the barrel of the ERM or TCP. The procedure for this is currently in development (see T1000626 for the test log) and will be covered in a different document.

The document starts with giving an overview of the required tooling followed by giving the relevant documentation. It then discusses the detailed steps of the procedure including location, timing, number of personnel needed and tooling needed.

## 1.2 Equipment and Materials

- Quality control documentation mass, prisms, jig
- Filtered dry nitrogen
- Dry nitrogen air gun or unplugged de-ionizing gun (unplug at least 5 minutes before use with flammable liquid)
- High intensity light source (ideally handheld battery supported)
- Cleanroom wipes
- Methanol or isopropanol - reagent grade
- Acetone – reagent grade
- 2x V-block - D1001685
- Bonding jig with prism holder – D1002201 and/or D1002140
- Metric slip gauges
- Allen key for #2-56 socket-head cap screw
- Digital calipers – with metric setting
- EP30-2 Adhesive cartridge for 10:1 mixing ratio and gun kit
- UHV aluminium foil
- Uncoated copper wire  $\varnothing$  0.5 mm
- 1 mm pin
- Airbake oven
- Petri dish
- Ergo-arm

- Coordinate measuring machine
- Earthquake stop mount plates (D080244 and ??)
- Ergo-arm with ERM/CP/ITM/ETM vacuum plate (D1002605 with D1002747)
- Inspection fixture (D1000812)
- (razor blade)

### 1.3 References

<b><i>Design documentation ‘glass’ essentials</i></b>	
D1000980	adLIGO, assembly of TCP optic with prisms
D1000979	aLIGO, COC TCP substrate
D080116	End Reaction Mass (ERM)
D0902822	Assembly of ERM optic with prisms
<b><i>Design documentation metal essentials</i></b>	
D080750	aLIGO SUS ERM wire break-off prism
D080241	Adv. LIGO, SUS, Earthquake Stop Assembly
D080244	ADV LIGO, SUS, QUAD N-PTYPE TEST REACTION MASS, EARTHQUAKE STOP MOUNT PLATE
D1003106	ITM thin CP bump stop
D1003107	ITM thin CP bump stop mount
<b><i>Design documentation of the alignment jigs</i></b>	
D1002140	aLIGO TCP prism bonding jig
D1002201	aLIGO ERM prism bonding jig
<b><i>Measurement reports on ‘glass’ essentials</i></b>	
Q1000009	Inspection document for the wire break-off prisms for the ERM
<b><i>Background documents</i></b>	
D0902001	aLIGO CP, TCP COC container assembly
D1000958	aLIGO, TCP (THIN COMPENSATION PLATE) SUBSTRATE ADAPTER
D1000812	OPTICS INSPECTION FIXTURE, CP, aLIGO, COC
D1002605	Ergo arm top level assembly drawing
D1002747	ERM/CP/ITM/ETM Optic Ergo-arm vacuum plate
E960022	LIGO Vacuum Compatibility, Cleaning Methods and Qualification Procedures
E0900394	aLIGO Optic Container Shipping Procedure

E970154	LARGE OPTICS SUSPENSION BALANCING SPECIFICATION
E1000386	Material Qualification RGA Test Results: MasterBond EP30-2 epoxy
T1000082	Ergo Arm Users Manual
E1000079	Procedure for Applying and Removing First Contact
T0900402	Enhanced LIGO Core Optic Drag Wipe Cleaning Procedure
T1000137	Drag Wiping and First Contact
T1000667	Revised Quad Suspension Design for Thin Compensator Plate
M1200294	Stop Work for Adhesive Bonding of Elements to Optics
T1200130	Ion gun use and safety eyewear training
T1200321	Guidelines on protecting the Cavity Optics in chamber wrt First Contact
E1200821	Guidelines for use in de-bonding of epoxy bonds from optics

#### 1.4 Version history

02/12/10: Release v1 onto DCC. This version is meant for discussion purposes and is very much still a draft.

10/12/10: Release v2 onto DCC. In this version questions stated in v1 and other questions have been answered and the procedure has been changed to comply with the answers.

9/5/12: -v3. Updated steps involving de-ionizing gun to conform to T1200130. Updated gluing procedure to conform to M1200294 (new temperature; use of airbake oven; removing and reapplying First Contact). Revised de-gluing section to use acetone rather than detergent.

9/12/12: -v4. Removed detailed procedure for de-gluing in favour of a reference to E1200821.

## 2 Main procedure for gluing the wire break-off prisms

### 2.1 Set jig for the relevant side (on surface S3 at arrowed registration mark (ARM or 180° w.r.t. ARM) of the mass

Step	What	Where	Time	People	Tools
1	Choose which side (on surface S3 at arrowed registration mark (ARM) or 180° w.r.t. ARM) to bond the prism, select a prism, prism holder and bonding jig that will be used for the bonding. Calculate the required settings for $D_{\text{slider}}$ and $D_{\text{screw1}}$ for the bonding jig using the excel spreadsheet (E1000828).	In office	30 min	2 (one calculator, one checker)	Quality control documentation of mass, prism and bonding jig.
2	Set $D_{\text{screw}}$ on the left side of the jig for bonding at the ARM or the right side of the jig for bonding at 180° w.r.t. the ARM. For a nominal mean width of 130.00 mm for the ERM and 100.00 mm for the TCP, $D_{\text{screw}}$ will be set to 3.00 mm. Because of the $\pm 0.5$ mm variation on this though, in really this value will be slightly different for each mass. $D_{\text{screw}}$ is most easily and most accurately set using slip gauges	in bonding cleanroom	5 min	1	Bonding jig assy (D1002140 for the TCP, D1002201 for the ERM), metric slip gauges
3	Set $D_{\text{slider}}$ on both sliders of the jig. This is for the vertical alignment of the jig. Since the prisms will be glued onto the centerline, the distance between the top of the alignment pin and the slider shall be 20.00 mm. $D_{\text{slider}}$ is most easily set using (digital) calipers.	in bonding cleanroom	5 min	1	Bonding jig assy, digital metric calipers, #2-56 socket-head cap screw
			<b>40 min</b>		

### 2.2 Set-up mass and prism for cleaning

Step	What	Where	Time	People	Tools
4	Open the storage container following the procedure E0900394. Surface S1 (with the ESD gold pattern) of the optic will be facing down inside the storage container.	in bonding cleanroom	5 min	2	Optic in storage container, storage container tools
5	Use the ergo-arm to lift the optic out of the container (the ergo-arm should only ever lift the optic on surface S2 (NO ESD pattern). Place the	in bonding cleanroom	10 min	2	Ergo-arm, V-block, isopropanol

Step	What	Where	Time	People	Tools
	optic onto the V-block on the table with the bonding side facing up. Follow instructions for the ergo-arm (T1000082).				cleanroom wipes
6	Change gloves	in bonding cleanroom	1 min	2	gloves
7	Take the prism out of its packaging and place in a petri dish on a clean room wipe. It is a stainless steel prism.	in bonding cleanroom	2 min	1	Prism (D080750), petridish, cleanroom wipe
8	Change gloves	in bonding cleanroom	1 min	2	gloves
			<b>19 min</b>		

**2.3 Clean the relevant side (ARM or 180° w.r.t. ARM) of the mass**

Step	What	Where	Time	People	Tools
9	Get the dry nitrogen air gun ready. If the air gun has an ionizer not rated for use with flammable liquid, the ionizer must be unplugged or otherwise de-energized at least five minutes prior to use and remain so throughout the procedure. Ensure the dry nitrogen supply is open and the air gun can blow a gentle consistent and well-controlled flow.  Make sure acetone, methanol and cleanroom wipes are ready.	in bonding cleanroom	1 min	1	Dry nitrogen, acetone, isopropanol or methanol, clean room wipes
10	Use the drag wiping procedure to carefully wipe the relevant side with acetone. Repeat with isopropanol or methanol.	in bonding cleanroom	1 min	1	Acetone, isopropanol or methanol, optical wipes
11	Use the air gun to gently blow dry the bonding area	in bonding cleanroom	1 min	1	Dry nitrogen
			<b>3 min</b>		

**2.4 Clean prism**

Step	What	Where	Time	People	Tools
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Step	What	Where	Time	People	Tools
12	Take the prism holder and wipe with methanol to remove any dust particles. Blow dry with nitrogen.	In bonding cleanroom	30 sec	1	Prism holder, cleanroom wipe, methanol
13	Turn the grub screw on the prism holder back so that the prism can easily be put into the holder.	In bonding cleanroom	1 min	1	Fingers should be enough, Allen key for #2-56 socket head cap screw
14	Pick up the prism. Apply some acetone to another wipe and wipe the surface to be bonded carefully. Repeat with isopropanol or methanol. Blow dry with nitrogen.	in bonding cleanroom	1 min	1	Acetone, Isopropanol or methanol, cleanroom wipes
15	Carefully put the prism into the prism holder ensuring it sits comfortably against all three support rods. Then tighten the grub screw such that it is just tight enough to prevent the prism from falling out of the prism holder.	In bonding cleanroom	1 min	1	Fingers should be enough, Allen key for #2-56 socket head cap screw
16	Put on clean gloves	in bonding cleanroom	30 sec	1	Gloves
			<b>4 min</b>		

## 2.5 Prepare the adhesive

Step	What	Where	Time	People	Tools
17	Make a small boat of clean UHV aluminium foil	in bonding cleanroom	1 min	1	UHV aluminium foil
18	Prepare a couple of applicator wires ( $\varnothing 0.5$ mm uncoated copper wire). Wipe them with acetone followed by a wipe with isopropanol or methanol.	in bonding cleanroom	1 min	1	$\varnothing 0.5$ mm uncoated copper wire, acetone, isopropanol or methanol
19	The EP30-2 adhesive comes in a 37 ml gunkit, which can mix a 10:1 adhesive ratio (see E1000386). Place the adhesive cartridge in the gun. Remove (but save) the end cap and replace it with the mixing tube. Prime	in bonding cleanroom	2 min	1	EP30-2 gun kit, EP30-2 adhesive cartridge for 10:1

Step	What	Where	Time	People	Tools
	the mixing tube and then dispense adhesive onto scrap UHV foil for at least one trigger-pull's worth or until the adhesive is emerging well-mixed (the initial flow is sometimes runny).				mixing ratio (EP30-2 2ml bipack with 10:1 mixing ratio)
20	Dispense adhesive into the UHV foil boat using the gun - enough to create a pool about 1" in diameter.	in bonding cleanroom	1 min	1	UHV aluminium foil, (Clean razor blade or scissors)
21	After using the mixing tube and gun, detach the mixing tube and throw away the mixing tube. Reattach the end cap and store the gun with the cartridge attached to the gun.	in bonding cleanroom	1 min	1	
			<b>6 min</b>		

## 2.6 Gluing the prism onto the side

Step	What	Where	Time	People	Tools
22	Use the fibre optic light to thoroughly inspect the surface for small specks from a distance of 5-6". Wipe and/or blow any specks away.	in bonding cleanroom	1 min	1	Optical wipe, methanol, dry nitrogen
23	Wipe down the bonding jig with methanol to remove any dust and blow dry with nitrogen. Place the jig on the bonding surface by referencing surface "S1" (with the ESD gold pattern) of the mass and lining the sliders up with the fiducial line in the surface ("S3"). Be careful not to slide the micrometer screw contact points against surface S1 until vertical alignment has been achieved as this might cause marks in the mass. Tighten the spring-loaded screw onto surface "S2".	in bonding cleanroom	3 min	1	Optical wipe, methanol
24	Check the prism for dust one last time. Wipe with methanol if necessary. Blow dry with dry nitrogen.	in bonding cleanroom	1 min	1	
25	Dip the end of the copper applicator wire into the adhesive in the aluminium boat. Drag a thin layer of adhesive along its length on each	in bonding cleanroom	1 min	1	Uncoated copper applicator wire

Step	What	Where	Time	People	Tools
	side onto the prism.				
26	Pick up the prism holder with prism and put the prism down onto the mass while referencing the prism holder against the top left corner of the bonding jig. Apply some mild pressure to make the adhesive spread.	in bonding cleanroom	1 min	1	
27	Leave the remainder of the adhesive in the boat beside the mass. Leave the adhesive to cure overnight at room temperature (12-16 hrs).	in bonding cleanroom	12-16 hrs	0	
28	On return, check the adhesive in the boat has cured by breaking it. It should break in a brittle way.	in bonding cleanroom	1 min	1	
29	Loosen the grub screw on the prism holder and carefully remove it. Then loosen the spring laden screw on the jig and carefully remove the jig from the mass. For the CP it might be difficult to reach the grub screw because of limited room. A 1 mm diameter pin can help here or remove the bonding jig first before removing the prism holder.	in bonding cleanroom	2 min	1	1 mm diameter pin
30	Use a Coordinate Measuring Device to measure the position of the prism with respect to the front and back and the fiducial line to confirm the prism is in the correct position	in bonding cleanroom	1 hr	2	Coordinate measuring device
			<b>7 min</b>	<b>1</b>	
			<b>12 hrs</b>	<b>0</b>	
			<b>63 min</b>	<b>2</b>	

### 2.7 Glue the prism on the other side

Step	What	Where	Time	People	Tools
31	Use the ergo-arm (lifting the mass on side S2) to turn the mass 180° to allow for bonding the prism onto the other side.	in bonding cleanroom	10 min	2	First Contact, clean room wipes
32	Repeat steps 1 through 3 and 6 through 26.	In office/ in bonding cleanroom	26 min	1,2	See above
33	Repeat the curing steps 27 through 30.	In bonding	12 hrs +	0,1	See above

Step	What	Where	Time	People	Tools
		cleanroom	63 min		
			<b>35 min</b>	<b>2</b>	
			<b>12 hrs</b>	<b>0</b>	
			<b>63 min</b>	<b>2</b>	

### 3 Procedure for attaching the earthquake stop bases

Step	What	Where	Time	People	Tools
34	Use the ergo-arm to put the mass back onto the second ring of the inspection/flipping fixture.	In bonding cleanroom	10 min	2	Ergo-arm, storage container baseplate with O-ring
35	Add first ring of inspection/flipping fixture and complete assembly.	In bonding cleanroom	5 min	2	Inspection fixture
36	Lift the optic with two persons and turn the optic over so that surface S1 is facing up. Remove second ring, so that surface S1 can be accessed.	In bonding clean room	5 min	2	
37	Wipe the bonding locations for the earthquake stop mount plates with acetone and methanol or isopropanol.  The TCP does not have recesses in the surface for the mount plates. Locations are easily recognizable by the circular spaces that have been created in the gold ESD pattern.  The ERM does have recesses in the surface in which the mount plates can be located. Clean room buds will be needed to clean the recesses.	In bonding cleanroom	1 min	1	Cleanroom wipes, cleanroom buds, acetone and methanol or isopropanol
38	Prepare 4 earthquake stop mount plates (D080244 for the ERM, D1003107 for the TCP) by wiping them with acetone followed with a wipe with isopropanol or methanol. Blow dry with dry nitrogen and place them into a petri dish with a clean cleanroom cloth.	in bonding cleanroom	1 min	1	4 earthquake stop mount plates (D080244 or D1003107) cleanroom wipes,

Step	What	Where	Time	People	Tools
39	Prepare the adhesive as described in steps 17 to 21.	in bonding cleanroom	7 min	1	acetone, methanol or isopropanol, petridish See above
40	Dip the applicator wire in the EP30-2. Take one of the mount plates and apply a small drop ( $\varnothing$ 0.5 – 1.0 mm) to the centre of the back surface.	in bonding cleanroom	1 min	1	0.5 mm uncoated copper wire, acetone, methanol or isopropanol,
41	Carefully place the mount plate down into one of the 4 recesses for the ERM, or in the centre of one of the circular cut-outs in the gold ESD pattern on the TCP. Apply some light pressure to allow the adhesive to spread but be careful not to let the plate slide. The required accuracy is +/- 0.5 mm.	in bonding cleanroom	1 min	1	
42	Repeat steps 41 and 42 until all 4 mount plates have been glued.	in bonding cleanroom	8 min	1	
43	Leave the remainder of the adhesive in the boat beside the mass. Leave the adhesive to cure at room temperature.	in bonding cleanroom	12-16 hrs	0	
44	Check the adhesive in the boat has cured by breaking it. It should break in a brittle way.	in bonding cleanroom	1 min	1	
			<b>24 min</b>		
			<b>12 hrs</b>		
			<b>23 min</b>		
			<b>12 hrs</b>		
			<b>31 min</b>		

#### 4 Final airbake,

Step	What	Where	Time	People	Tools
45	Set up the V-block in a cold (room-temperature) airbake oven.	In bonding cleanroom	1 min	1	V-block, airbake oven

Step	What	Where	Time	People	Tools
46	Using two people and the inspection/flipper fixture, turn the optic over onto the baseplate of the cake tin fit with the ring spacer (D1100501) so that the S2 surface is uppermost and the Macor EQ stop bases are protected.				
47	Use the ergo arm to pick up the optic by the S2 face and move it onto the V-block in the oven.	In bonding cleanroom	5 min	2	ergo-arm
48	Remove First Contact from both sides of the optic.		30 min	1	ion gun, Berkshire lint free wipes, acetone
49	Set the oven for a maximum temperature of 34°C with a ramp rate of 1.5°C per minute or less.	In bonding cleanroom	1 min	1	
50	Bake the optic for 6 hours, monitoring the temperature with a thermocouple from time to time to check that it does not exceed the above ramp rate or maximum temperature.	In bonding cleanroom	6 hrs	0	thermocouple
51	Switch off the oven and allow the optic to cool.	In bonding cleanroom	30 min??	1	
52	Soon after the optic has reached room temperature, use the ergo-arm to pick it up by the S2 face and move it back to the inspection/flipping fixture.	In bonding cleanroom	5 min	2	ergo-arm
53	Pour First Contact on the S2 face to form a film over the whole face and allow to dry.	In bonding cleanroom	2-8 hours	1	First Contact
54	Once the First Contact is mostly dry, using two people, turn the mass over.	In bonding cleanroom	5 min	2	flipper fixture
55	Pour First Contact on the centre of the S1 face to form a film over the centre region, stopping short of the gold electrodes. Allow to dry.	In bonding cleanroom	2-8 hours		First Contact
56	Using two people, turn the mass over and place it on the base of the storage container.				flipper fixture , storage container
57	Reassemble the storage container around the optic and take the optic to storage.	In bonding cleanroom/ mass storage	10 min	2	ergo-arm, storage container

Step	What	Where	Time	People	Tools
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## 5 Back-up and other procedures

### 5.1 Removing a prism or earthquake stop base

In the case that a prism is not aligned to the required accuracy or the adhesive has not cured well, it will be necessary to remove the prism. This can be done at any time per the procedure in E1200821. The optic should always be taken out of the structure for de-gluing.

### 5.2 Applying/removing First Contact

See T1200321 for general policy on when to apply and remove First Contact, and E1000079 for a detailed procedure.