LIGO Laboratory / LIGO Scientific Collaboration

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ALIGO NP-type: - Report on Prism Bonding at LASTI on 11th – 17th February 2008

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Introduction

In the week of Monday 11th until Friday 15th February 2008 a third exercise was done at LASTI for glueing prisms to the first and second penultimate mass and the reaction mass as part of the ALIGO ETM/ITM noise prototype activity.

Preceding bonding exercises were done from 27th – 31st August 2007 and 10th – 15th December 2007 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.

This document reports on the experiences gained during this 3rd exercise with bonding prisms.

1 Reference documents

Design documentation 'glass' essentials	
D050421-A	NP- type ETM Penultimate Mass
D050420-A	NP-type ETM Reaction Test Mass
D060166-05-B	NP-type Reaction Test Mass Wire Break-off Prism
D060099-03-B	NP-type Penultimate Mass Break-off Prism
Design documentation of the alignment jigs	
D070391-01-D	NP-type ear bonding jig GA
D070505-00-D	NP-type penultimate mass prism holder
D070507-00-D	NP-type ERM Prism bonding jig
D070504-00-D	ERM prism holder bonding
Measurement reports on 'glass' essentials	
GNL-4025-R1	Penultimate mass 1 measurements
GNL-4027-R2	Penultimate mass 2 measurements
GNL-4020-R1	Reaction mass measurements
T080042-00-K	Test report prisms
Back ground documents	
T080020-00-D	ALIGO NP-type: - Preparations of Prism Bonding at LASTI on 11th – 17th February 2008
T080023-00-R	Test prism glueing on disc insert plates
T070138-00-K	Ribbon/Fibre Length Budget
T070156-01-K	Advanced Testing of the Noise Prototype Ear Bonding Jig
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
E970154-00-D	Large optics suspension balancing: component specification

2 Goals

Goals of the visit were to:

1) Measure the positions of the ears on the 2nd penultimate mass
2) Glue prisms to the 2nd penultimate mass
3) Glue prisms to the 1st penultimate mass
4) Glue prisms to the reaction mass

3 Time schedule

Both the prospected and actual time schedule are shown in Table 3.1. It was decided to glue prisms on the 1st penultimate mass first, because it is unlikely that this mass will be used for the actual LASTI suspension. It was felt that that would give us some additional practice.

Bonding prisms was done more in parallel, than was prospected, glueing a side on two masses with one batch of adhesive. The 4 day window is necessary though, because the adhesive needs to cure for 24 hours.

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

	Monday 11-02-2008		Tuesday 12-02-2008		Wednesday 13-02-2008		Thursday 14-02-2008		Friday 15-02-2008	
Preparations										
Measure position of the ears on 2nd penultimate mass										
Glue prisms to side 1 2nd PM										
Glue prisms to side 2 2nd PM										
Glue prisms to side 1 ERM										
Glue prisms to side 2 ERM										
Glue prisms to side 1 1st PM										
Glue prisms to side 2 1st PM										
Pack masses and clean										

4 List of required items

Essentials

- Prisms (2x 2-Groove Lithosil for the 1st and 2nd penultimate masses, 4x 1 groove F2 glass (15% lead) for the reaction mass, plus spares). We have 12 prisms. The grooves have been made using a technique called laser ablation. Ionisation of the lead in the F2 glass caused yellow coloured stains in the F2 glass. These do not inhibit performance.
- Masses (2 penultimate masses and reaction mass)

Bonding Jigs

- 1 full bonding jig 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
- Alcohol

Large items

- Ergo arm and ring clamp
- V-blocks
- 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
- Infrared thermometer

5 Preparations

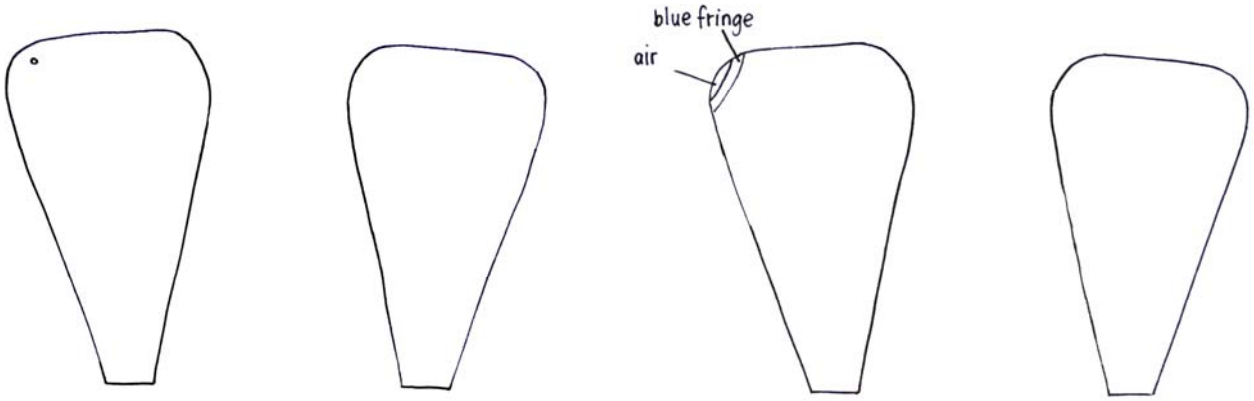
Tuesday morning 12th of February

- Filled in safety form with Rich Mittleman. Mariëlle van Veggel was appointed task leader.
- Check if all required items are accounted for.
- Set-up the clean room and clean equipment.

6 Observations of the bonds on the 2nd penultimate mass

6.1 Observations of the bonds

The bonds on the 2nd penultimate mass showed that a bit of air was still left in the corner of ear AA014 (Figure 6.1 b) and a small bubble was still present in ear AA010 (Figure 6.1 a). All other bubbles had disappeared.



a) Ear AA010 and ear BB005 on side 1 **b) Ear AA014 and ear BB012 on side 2**

Figure 6.1 Observations of the ears on the 2nd penultimate mass

6.2 Measurements of the positions of the ears

The positions of the ears were measured with the same method as was done with the 1st penultimate mass and the test mass during the second bonding trip T070305-00-D. Figure 6.2 shows the different symbols for the measured dimensions. The distance of the weld horns of the ears to the fiducial line (center of mass) is indicated by $d_{ear\ 1}$ and $d_{ear\ 2}$. The distances from the outer parts of the weld horns of the ears to the front and back surface are $w_{ear\ front}$ and $w_{ear\ back}$ respectively. The distance between the ears is w_{ears}.

The measurement results are shown in Table 6.1 and Table 6.2. On both sides the ears were perfectly centralized with respect to the center of mass. The ear height offset on bonding surface 1 that was already observed during the second bonding trip was measured to be 0.7 mm.

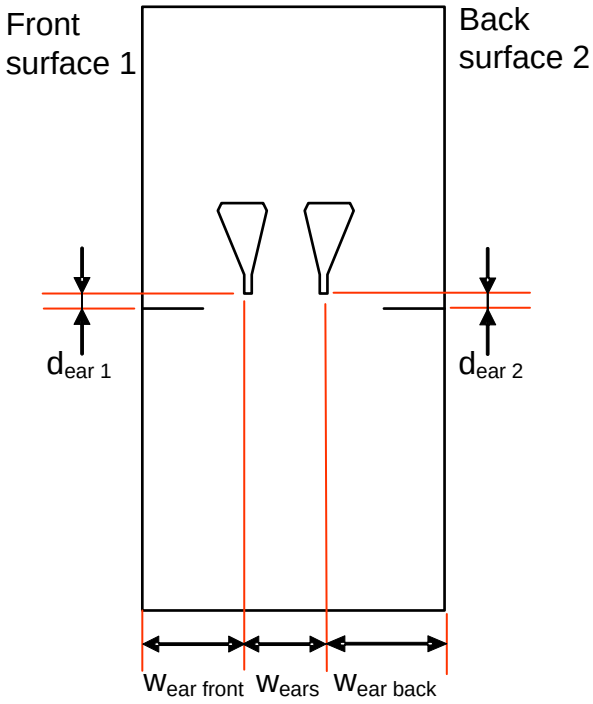


Figure 6.2 Measurement of position of ears (back surface is the surface with the magnet dimples)

$w_{ear\text{-}front}$ and $w_{ear\text{-}back}$ should be 100.2 – 14.75 = 85.45 mm

w_{ears} should be 29.5 mm

The vertical position of the ears should be:

d_{ear} = d-pin + d_{jig} – d-slider = 19.0 + 2.25 – 18.6 = 2.65 mm

Table 6.1 Measurements of the position of the ears on the 2nd PM on bonding side 1

Parameter	**Measured value [mm]**
$w_{ear\text{-}front}$	85.5 mm, 85.5 mm, 85.5 mm (85.5 mm)
w_{ears}	29.6 mm, 29.6 mm, 29.4 mm (29.6 mm)
$w_{ear\text{-}back}$	85.4 mm, 85.5 mm, 85.4 mm (85.4 mm)
$d_{ear\ 1}$	3.0 mm, 2.95 mm, 2.8 mm, 2.77 mm (2.9 mm)
$d_{ear\ 2}$	2.35 mm, 2.24 mm, 2.15 mm (2.2 mm)
	Error value [mm]
$\varepsilon_h = 100.2 - (w_{ear\text{-}front} + w_{ears}/2)/2$	0 mm
$\delta d_{ear} = d_{ear\ 1} - d_{ear\ 2}$	0.7 mm

Table 6.2 Measurements of the position of the ears on the 2nd PM on bonding side 2

Parameter	**Measured value [mm]**
$w_{ear\text{-}front}$	85.4 mm, 85.4 mm, 85.4 mm (85.4 mm)
w_{ears}	29.5 mm, 29.5 mm, 29.5 mm (29.5 mm)
$w_{ear\text{-}back}$	85.4 mm, 85.4 mm, 85.4 mm (85.4 mm)
$d_{ear\ 1}$	2.1 mm, 2.3 mm, 2.3 mm, 2.2 mm (2.2 mm)
$d_{ear\ 2}$	2.0 mm, 2.2 mm, 2.2 mm, 2.3 mm (2.2 mm)
	Error value [mm]
$\varepsilon_h = 100.2 - (w_{ear\text{-}front} + w_{ears}/2)/2$	0 mm
$\delta d_{ear} = d_{ear\ 1} - d_{ear\ 2}$	0 mm

7 Prism glueing

7.1 Prism allocation

The prisms as they have been glued to the masses are shown in Table 7.1.

Table 7.1 Allocated prism numbers for the different masses

Mass	**Side 1**	**Side 2**
1st penultimate mass	Litho_prism_1	Litho_prism_2
2nd penultimate mass	Litho_prism_3	Litho_prism_4
Reaction mass left prism	F2_prism_1	F2_prism_3
Reaction mass right prism	F2_prism_2	F2_prism_4

Penultimate mass spares: Litho_prism_5, Litho_prism_6

Reaction mass spares: F2_prism_5, F2_prism_6

7.2 Template settings

7.2.1 Template for the penultimate masses

- The template for the penultimate masses is shown in Figure 7.1 (D070391-01 Bonding jig GA). The following distances need to be set for the two penultimate masses: D-screw1, D-screw2 and D_slider.

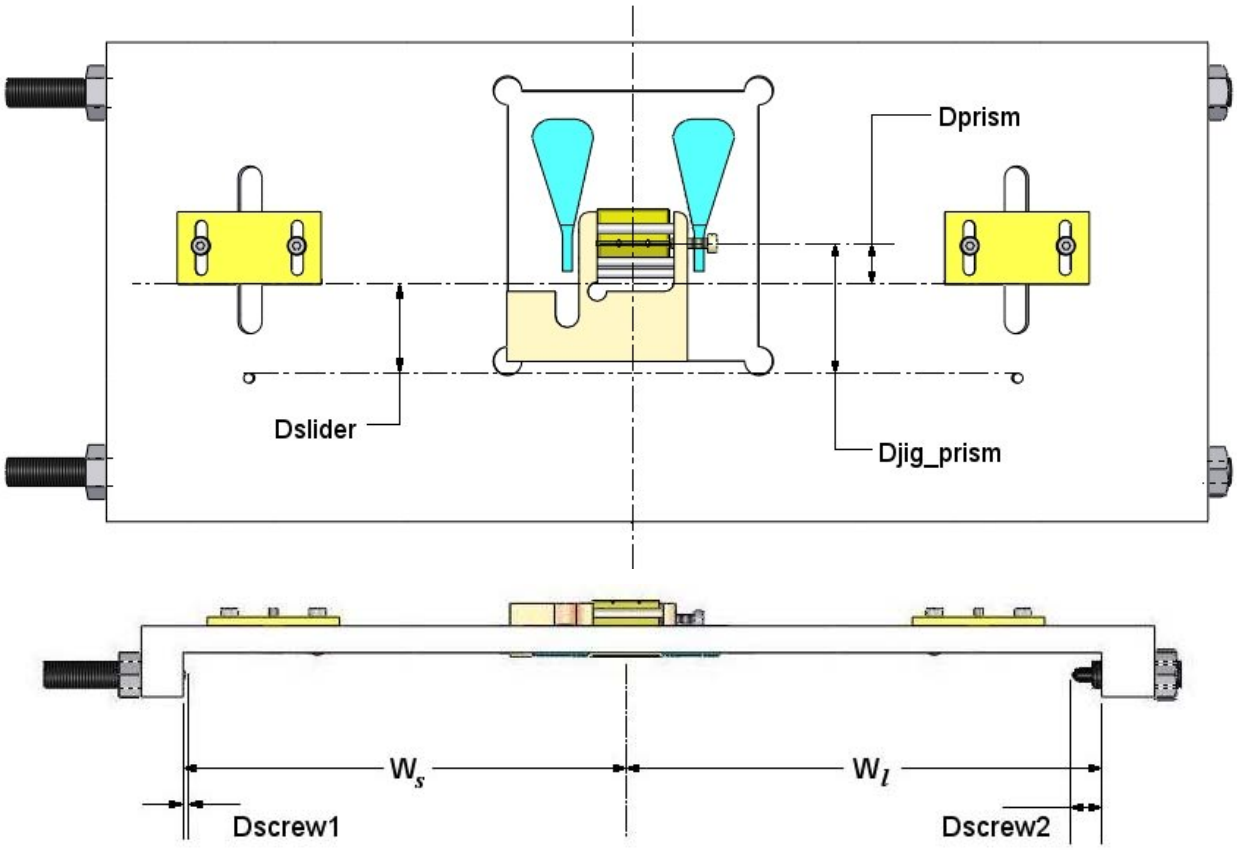


Figure 7.1 Template for penultimate masses

- D-slider for the penultimate masses will be set such that the tip of the prisms is D_prism = 7 mm above the centre of mass (the flexure points are 1 mm below the centre of mass).

  Djig_prism = 8.4 + 19.0 = 27.4 mm

  D_slider = Djig_prism – D_prism = 27.4 – 7 = 20.4 mm

- The presumption is made that the fiducial lines on the masses match up with the centre of mass.
- The measured width of the 1st penultimate mass $W_{1st\ PM}$ = 200.5 mm (single measurement) [1]
- The average width of the 2nd penultimate mass $W_{2nd\ PM}$ = 200.415 mm (average of 6 measurements)[2]
- The distances W_s and W_l of the jig sides for the 1st penultimate mass (PM jig) from the centre line were measured W_s = 100.3 mm and W_l = 108.0 mm to be sure that the prisms are centred when they are bonded to the mass.

[1] GNL-4025-R1 "1st Penultimate mass measurements"

[2] GNL-4027-R2 "2nd Penultimate mass measurements"

- The distances W_s and W_l of the jig sides for the 2nd penultimate mass (TM jig) from the centre line were measured W_s = 100.5 mm and W_l = 108.0 mm to be sure that the prisms are centred when they are bonded to the mass.

  The distance from the side to the prism reference surface of the prism holder was measured in Glasgow: $W_{prism\ holder}$ = 19.1 mm. The width of the prism W_{prism} = 15.0 mm. The distance of the template rectangular hole to the centre W_{hole} = 26.25 mm.

  The offset of the prism from the centre is:

  $e_{prism\ holder} = W_{hole} - W_{prism\ holder} - W_{prism}/2 = 26.25 - 19.1 - 7.5 = -0.35$ mm

  The settings of the screws for the 1st PM were calculated from:

  Bonding on flat 1 D-screw1 = $W_s - W_{1st\ PM}/2 - e_{prism\ holder}$ = 0.40 mm

  Bonding on flat 2 D-screw2 = $W_l - W_{1st\ PM}/2 + e_{prism\ holder}$ = 7.36 mm (see table 7.2)

  The settings of the screws for the 2nd PM were calculated from:

  Bonding on flat 1 D-screw1 = $W_s - W_{2nd\ PM}/2 - e_{prism\ holder}$ = 0.64 mm

  Bonding on flat 2 D-screw2 = $W_l - W_{2nd\ PM}/2 + e_{prism\ holder}$ = 7.40 mm (see table 7.3)

- The distances D-slider1 and D-slider2 were set using a set of calipers and a screw driver, like was done in T070223-00-K and T070305-00-D.
- The distances D-screw1 for flat 1, and D-screw 2 for flat 2 were set using a combination of slip gauges and feeler gauges and Allen keys and a spanner.

Table 7.2 Bonding jig setup for the 1st penultimate mass

	1st Penultimate Mass[3]	
	Flat 1[4]	**Flat 2[5]**
D-slider1 or D-slider 2	20.4 mm	20.4 mm
D-screw1	0.40 mm (±0.1)	(contact with sprung bolts)
D-screw2	(contact with sprung bolts)	7.36 mm (±0.1)

Table 7.3 Bonding jig setup for the 2nd penultimate mass

	2nd Penultimate Mass[6]	
	Flat 1	**Flat 2**
D-slider1 or D-slider 2	20.4 mm	20.4 mm
D-screw1	0.64 mm (±0.1)	(contact with sprung bolts)
D-screw2	(contact with sprung bolts)	7.40 mm (±0.1)

[3] D050421-05-K_Serial number 001 (1st of the two penultimate masses).

[4] D050421-05-D_Surface "S2" in zone "D8". Template referenced to front face, surface "S3".

[5] D050421-05-D_Surface "S1" in zone "D8". Template referenced to front face, surface "S3".

[6] D050421-05-K_Serial number 002 (the second of the two penultimate masses).

7.2.2 Template for the reaction mass

- The template for the penultimate masses is shown in Figure 7.2 (D070507-00 bonding jig reaction mass). The following distances were set for the two penultimate masses: D-screw1, D-screw2 and D_slider.

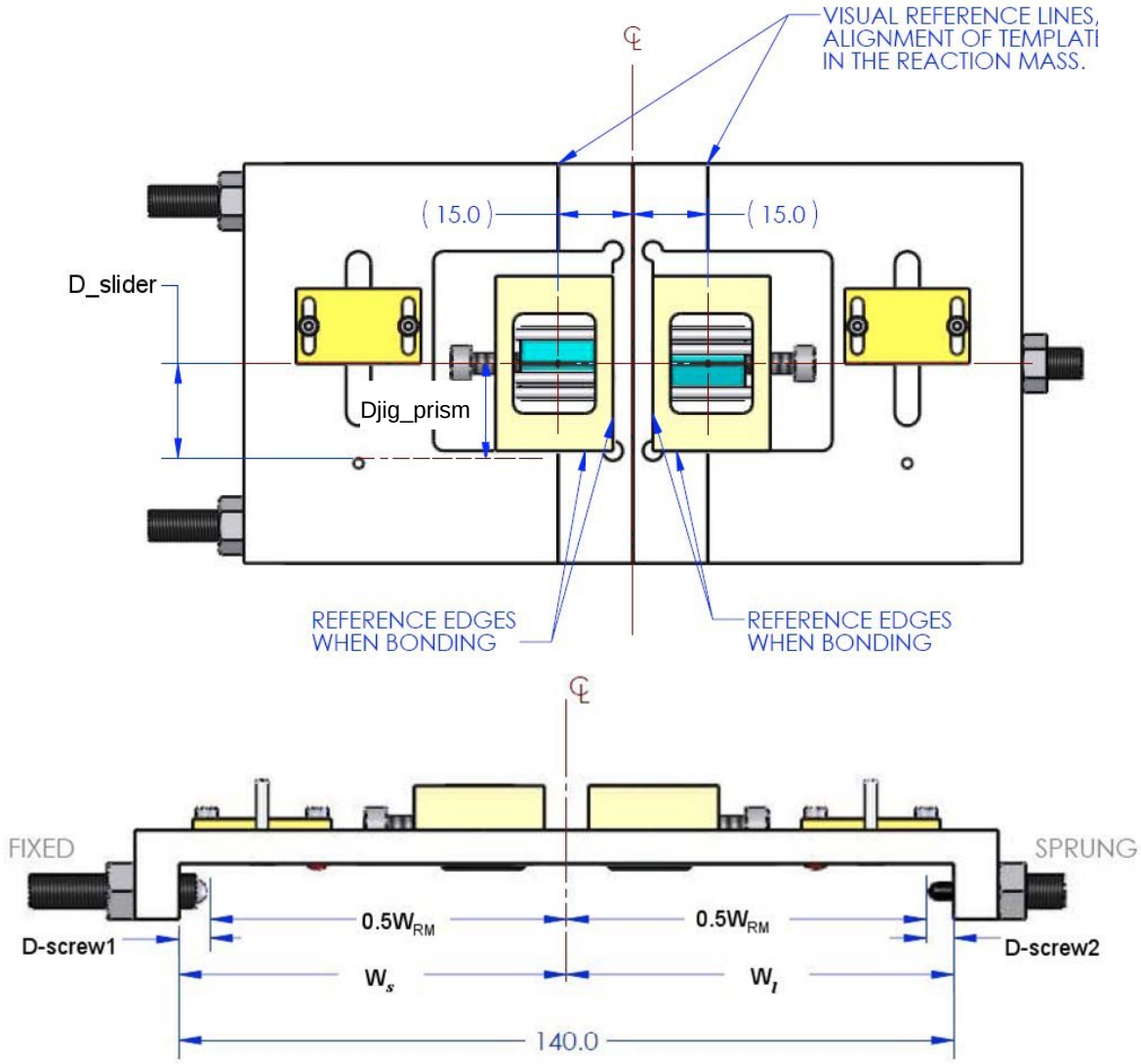


Figure 7.2 Bonding jig set-up for the Reaction Test Mass prisms

- D-slider for the reaction mass will be set such that the tip of the prisms is D_prism = 7 mm above the centre of mass.

  Djig_prism = 19.0 = 19.0 mm

  D_slider = Djig_prism – D_prism = 19.0 – 7 = 12.0 mm

  The reaction mass was adapted by drilling and tapping extra holes to accommodate for the slider to slide down low enough. With the original design the sliders could not go lower than 14.0 mm.

- The presumption was made that the fiducial lines on the masses match up with the centre of mass.

- The measured width of the reaction mass W_{RM} = 129.98 mm (single measurement)[7]
- The distances W_s and W_l of the jig sides from the centre line are W_s = 70.0 mm and W_l = 70.0 mm (confirmed).

  The settings of the screws for the 1st PM can be calculated from:

  Bonding on flat 1 D-screw1 = $W_s - W_{RM}/2$ = 5.01 mm

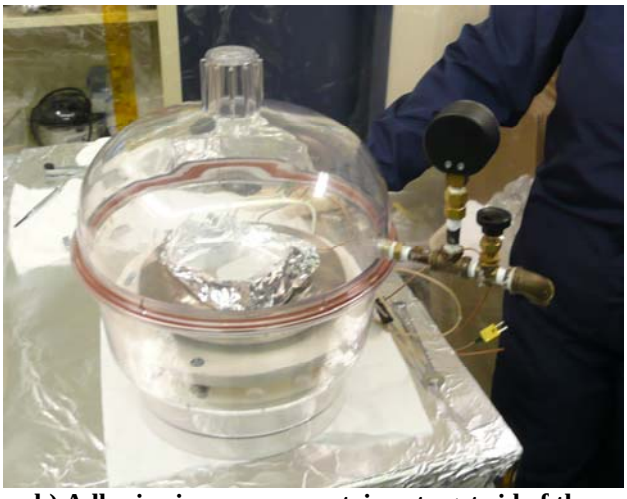
  Bonding on flat 2 D-screw2 = $W_l - W_{RM}/2$ = 5.01 mm
- The distances D-slider1 and D-slider2 are to be set using a set of calipers and a screw driver.
- The distances D-screw1 for flat 1, and D-screw 2 for flat 2 are to be set using a combination of slip gauges and feeler gauges and Allen keys and a spanner.

7.2.3 Prism glueing

The procedure for glueing the prisms using Perkin-Elmer Vac Seal adhesive is based on the procedure stated in E970154-D-D "Component specification".

- Prepared prisms in Glasgow by cleaning them in a bath of hot acetone followed by a bath of methanol and carefully packed them before they were taken to LASTI).
- Clean flat by wiping with methanol
- Setting prism glueing template on mass
- Clean prism by wiping with methanol.
- Put prism(s) into prism holder(s)
- Wipe prism with methanol
- Clean copper wire with acetone and methanol
- Make a boat of UHV aluminium foil and wipe it with methanol.
- Prepare Vac Seal adhesive: mix the two epoxy components of a Vac Seal "bipax" together thoroughly, approximately 2 minutes. Dispense from the middle of the container into the aluminium boat (Figure 7.3 a).

a) Dispensing the VacSeal in an aluminium boat



b) Adhesive in vacuum container to get rid of the bubbles

[7] GNL-4020-R1 "Reaction mass measurements"

Figure 7.3 Preparing VacSeal

- Put prepared Vac Seal in a vacuum container and connect a backing pump to evacuate air bubbles. The largest air bubbles did disappear but the vacuum of -25 mercury inches was not quite enough to evacuate all bubbles. It was therefore decided to dip in the wire at a spot with no visible bubbles (Figure 7.3 b).
  The first 3 prisms were glued with 'older' adhesive that Helena had brought from Caltech, were as all other prisms were glued with 'fresh' adhesive. It seemed that the fresher adhesive had more bubbles after mixing.
- Glue prism(s) to side 1: dip the applicator wire in epoxy and withdraw it, leaving a drop of epoxy on the wire. Apply epoxy on the wire as a drop to the bonding side of the prism. Spread the adhesive as a cross towards the corners of the prism over the surface. Lower the prism onto the flat of the mass (Figure 7.4).

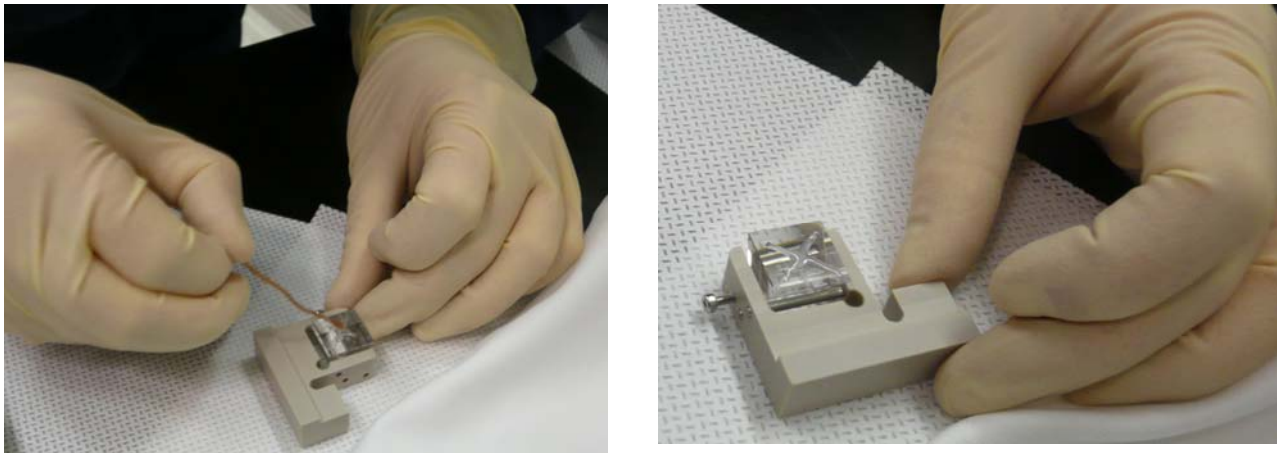


Figure 7.4 Applying adhesive to penultimate mass prism

- Cured the glued prism for at least 4 hours: using a 250 W heat lamp on a post lighting the prisms at a distance of about 20 cm (Figure 7.5). The exact times and number of hours the prisms were cured under the heat lamps are shown in Table 7.4 Using an infrared thermometer we measured the temperature to be around 60 °C.
- The aluminum boat with remaining adhesive was kept next to the bonds and checked after 24 hours by breaking is, to make sure the adhesive had cured properly.

Figure 7.5 Heat lamps on the two penultimate masses (13/02/2008)

Table 7.4 Bonding and curing times

Mass	Side	Date bonded	Time bonded	Curing time under heat lamp
2nd penultimate mass	Side 1	12/02/2008	14.56	19 hrs
	Side 2	13/02/2008	11.33	4 hrs
1st penultimate mass	Side 1	13/02/2008	11.33	4 hrs
	Side 2	14/02/2008	13.02	4 hrs
Reaction mass	Side 1	13/02/2008	17.48	17 hrs
	Side 2	14/02/2008	13.02	4 hrs

- Remove holders and template 24 hours after glueing the prisms onto the mass, since VacSeal needs 24 hours curing time at room temperature.
  During removing the jig from side 1 of the reaction mass the jig touched the right prism, causing a small chip. It is unlikely that this will inhibit performance.

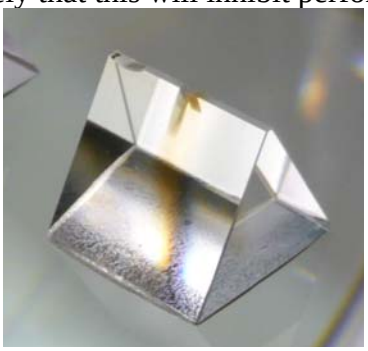
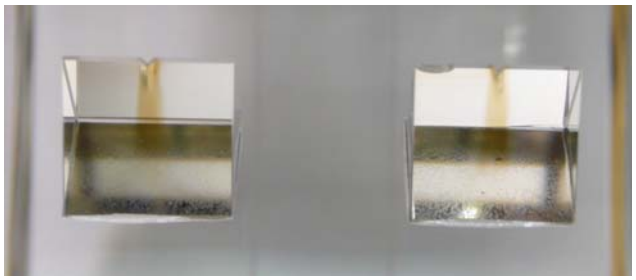


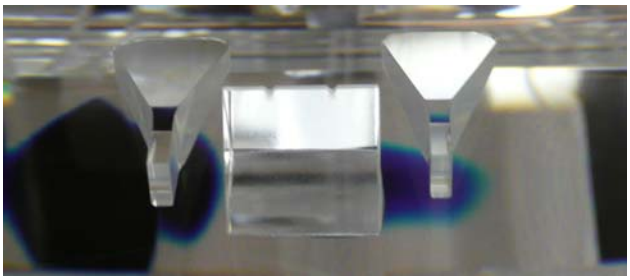
Figure 7.6 Chip on one F2 prism on side 1 of the reaction mass

8 Observations of the bonds

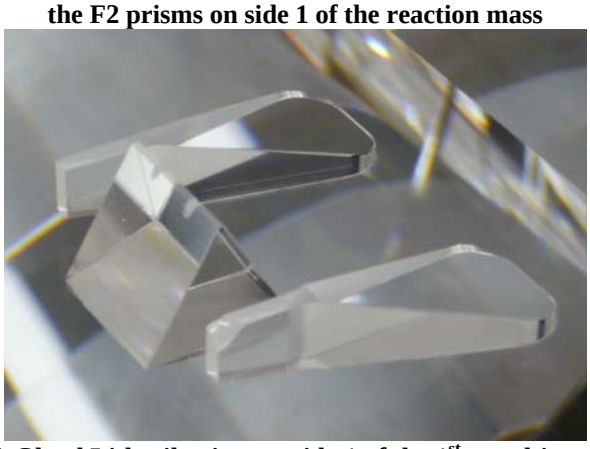
- The adhesive of the F2 prisms on the reaction mass showed a grainy and seemingly bubbly structure after 24 hrs of curing as is shown in Figure 8.1 a.
- The adhesive of the Lithosil prisms on the penultimate mass showed a clear bond as shown in Figure 8.1 b and c.
- It might be that the grainy structure of the adhesive is present in the Lithosil prisms as well, but that it is not visible.
- In all prisms the cross pattern in which the adhesive was dispensed onto the prism was visible after curing. The F2 prisms showed it more clearly than the Lithosil prisms Figure 8.1 d.



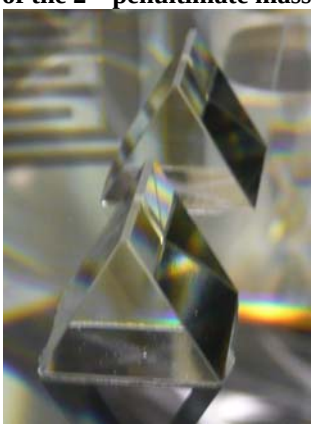
a) Grainy and seemingly bubbly adhesive structure in the F2 prisms on side 1 of the reaction mass



b) Adhesive structure in the Lithosil prisms on side 2 of the 2nd penultimate mass



c) Glued Lithosil prism on side 1 of the 1st penultimate mass



d) Cross pattern in the F2 prisms on side 2 of the reaction mass

Figure 8.1 Photographs of prisms after 24 hrs of curing

- Adhesion of the prisms was felt manually after 24 hrs of curing. Adhesion was okay for all.
- Observation of the alignment of the prisms by using the wire grooves and the fiducial lines showed a good alignment of the prisms. No measurements of the positions were done.

9 Conclusions

- The alignment of the ears in horizontal direction was correct within 0.1 mm. Ear AA010 on side 1 of the 2nd penultimate mass had an offset of 0.7 mm with respect to all other ears, of which the the tip of the weld horn was 2.2 mm above the centre of mass.
- Ear AA014 still showed an air bubble in the corner and ear AA010 still showed a small bubble in the corner. All other bubbles had disappeared.

- All prisms were glued onto the reaction mass and penultimate masses successfully at 7 mm above the centre of mass.
- Especially the prisms of the reaction mass showed a grainy and seemingly bubbly structure in the adhesive and the crossed pattern drawn with the copper wire was visible.
- Prism F2_prism2 was chipped when the jig was taken of the mass.