LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Bonding & visual inspection of preliminary test ears (Serial Numbers 0005, 0006, 0015 & 0016)

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1 Introduction

Preliminary test ears for the ETM/ITMs were fabricated to drawing number D050169-06 for initial bonded ear strength testing and visual inspection. The ears are Heraeus Suprasil 2 and have a bond area of 1.77cm^2 in accordance with the allowable limit set by thermal noise considerations[1]. They are designed in such a way as to accommodate a lap welded ribbon. *Vendor 'B'* and *Vendor 'A'* each were commissioned to fabricate an initial batch of ten of these ears (assigned ear Serial Numbers: 0001 to 0010 and 0011 to 0020 respectively) for a series of preliminary tests.

This document describes the bonding of four of these ears (serial numbers SN 0005 & 0006 (*Vendor 'B'*) and 0015 & 0016 (*Vendor 'A'*)) to silica disks (fabricated by *Vendor 'A'*) on 3rd August 2005 by H. Armandula. The silica discs were manufactured to drawing number D050192-01 with ϕ = 50 mm and t = 7 mm. There were two types of disk, namely Suprasil 312 and Spectrasil 2000.

Note: *Vendor 'A'* supplied Heraeus Suprasil 312 instead of Suprasil 2 discs for these tests as requested. However it was considered valuable to have data on Suprasil 2:312 bonds. Likewise Suprasil 2:Spectrasil 2000 bonds are also of interest.

To allow for adequate curing of the bonds it was planned that bond strength testing would be conducted four weeks after bonding by C. A. Cantley and R. Jones.

2 Bonding

Fresh silicate bonding solution was made up using the Advanced LIGO bonding procedure[2] (i.e. a concentration of 1 part commercial sodium silicate solution (14% NaOH, 27% SiO2) to 6 parts De-I water).

Four bonded sets were made. The materials used are summarized in Table 1.

Ear Serial Number	***Ear manufacturer***	***Ear material***	***Disk manufacturer***	***Disk material***
0005	*Vendor 'B'*	Suprasil 2A	*Vendor 'A'*	Suprasil 312
0006	*Vendor 'B'*	Suprasil 2A	*Vendor 'A'*	Spectrasil 2000
0015	*Vendor 'A'*	* Suprasil 2	*Vendor 'A'*	Suprasil 312
0016	*Vendor 'A'*	* Suprasil 2	*Vendor 'A'*	Spectrasil 2000

* Grade 2A or 2B not specified.

[1] Cantley et. al., "*Ear Bond Area Limit for ETM/ITM Optics from consideration of Thermal Noise*", T050216-00-K.

[2] Armandula, "*Silicate Bonding Procedure (Hydroxide-Catalysis Bonding)*", E050228-00-D.

Before cleaning, the global flatness of the disks was assessed using a Logitech LI10 interferometer. The disks looked reasonably flat with a typical interferogram shown in Figure 1.

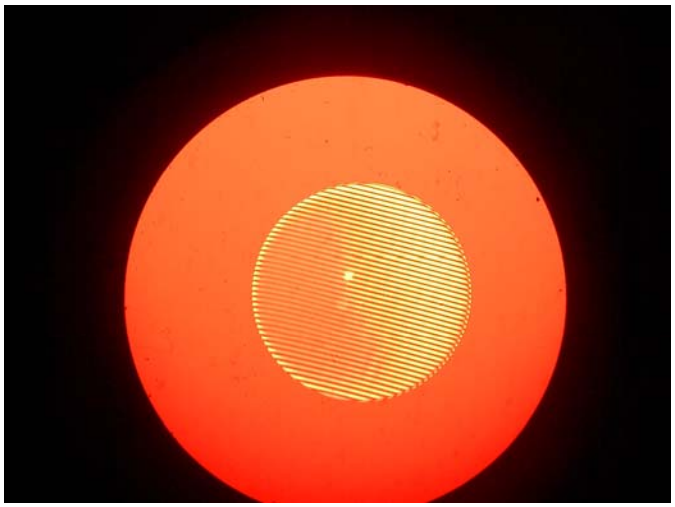

Figure 1 Typical disk interferogram

Before cleaning, the global flatness of each of the ears was also assessed.

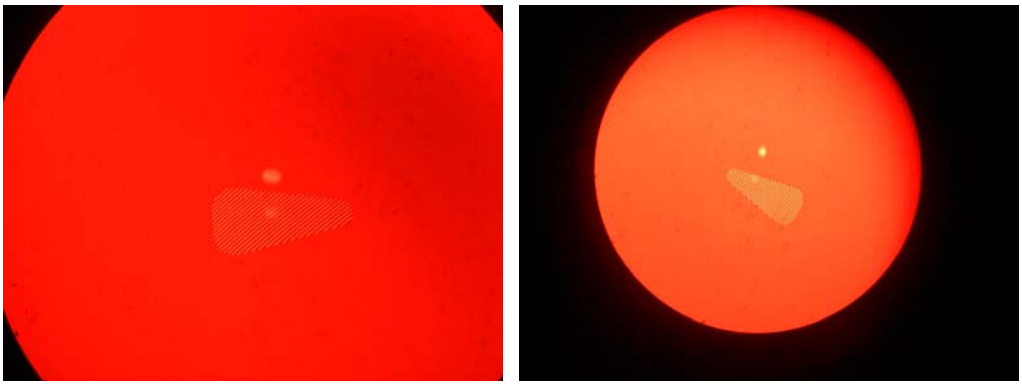

Figure 2 Interferograms of Vendor 'B' ears (Serial Numbers 0005 (left) & 0006 (right))

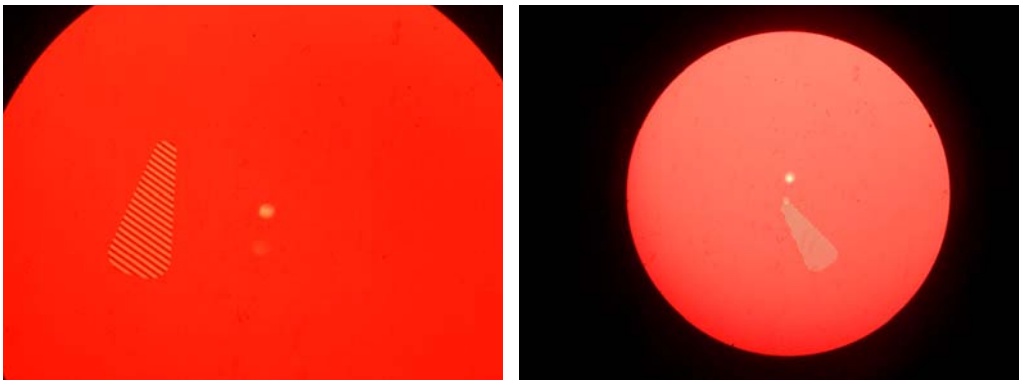

Figure 3 Interferograms of Vendor 'A' ears (Serial Numbers 0015 (left) & 0016 (right))

The interferograms of both sets of ears seemed reasonable (specification λ/10). For other *Vendor 'B'* ears within the same batch (SN 0001 to 0004) poorer flatness was observed[3] at more like λ/4.

The ears and flats were all cleaned using the procedure detailed in the Advanced LIGO bonding procedure[4].

To bond each ear/flat pair the same procedure was followed:

- A single drop of 0.8 microlitres of bonding solution was dispensed onto the surface of a flat using a biological pipette.
- An ear was then placed by hand over the drop and lowered until it touched the drop and flat beneath with the drop spreading out to fill the entire bonding surface

All bonds were left on the clean bench to cure.

Additional Comments:

The specified flatness for the bonding surface on the ears was λ/10. The other surfaces of these initial ears were specified as ground finish.

The ground finish was not ideal from two perspectives:

Bonding

1) the ground surfaces hindered inspection of the cleanliness of the polished bonding surface of the ear
2) the ground ear surfaces meant that the bonded interface could not be seen when the ear was put in place on the flat – so it was not possible to check that the bonding fluid had

[3] Rowan, Hough. Cantley, *"Bonding & Visual Inspection of Preliminary Test Ears (Serial Number 0011-0014)"*, T050121-00-K.

[4] Armandula, *"Silicate Bonding Procedure (Hydroxide- Catalysis Bonding)"*, E050228-00-D.

spread out correctly from above. However inspection could be carried out through the disc/flat after initial bonding.

Stress concentrations

3) Aside from causing visibility problems with respect to assessment of bond quality, it was considered that the ground finish could lead to undesirable concentrations of stress on the surface/edges of the ears when loaded. This was to be further investigated during loading tests on the bonded samples. It was considered that in these existing bonded test ears the surface quality could be improved by flame polishing. Future ears would be fabricated with an inspection polish to remove this problem.