**LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY**

*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO-T050121-00-K *Advanced LIGO* 14th July 2005

# Bonding & visual inspection of preliminary test ears (Serial Number 0011 – 0014)

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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 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 'A'* were commissioned to fabricate an initial batch of ten of these ears (assigned ear Serial Numbers: 0011 to 0020) for a series of preliminary tests.

This document describes the bonding of four of these ears (serial numbers SN 0011 to 0014) to silica discs (also fabricated by *Vendor 'A'*) on 14th July 2005 by S. Rowan and J. Hough. The silica discs were manufactured to drawing number D050192-01 with $\phi$ = 50 mm and t = 7 mm.

Note: *Vendor 'A'* supplied Suprasil 312 instead of Suprasil 2 discs for these tests. However it was considered valuable to have data on Suprasil 2:312 bonds.

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 during the visit to Glasgow of H. Armandula and J. Romie between 1st and 13th August 2005.

# 2 Bonding

Fresh silicate bonding solution was made up using the procedure described in the Advanced LIGO bonding procedure[2] (i.e. a concentration of 1 part commercial sodium silicate solution (14%NaOH, 27% $SiO_2$) to 6 parts De-I water).

Four bonded sets were made using the ears and flats manufactured by *Vendor 'A'* as described above (see Figure 1).

*Figure 1. Heraeus 'Suprasil 2' fused silica ears and 'Suprasil 312' flats manufactured by Vendor 'A'.*

[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 all four 'ears' was assessed using a Logitech LI10 interferometer (see Figure 2).

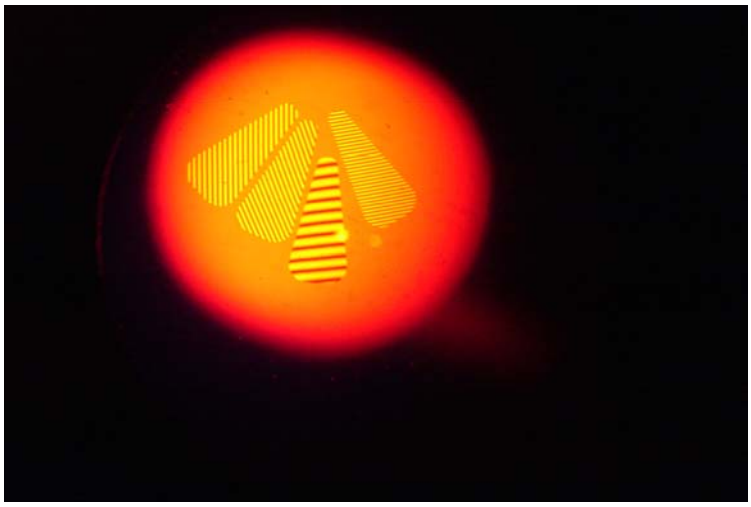

*Figure 2. Interferogram indicating flatness of 'as received' Suprasil 2 'ears' supplied by Vendor 'A'.*

The flatness of the silica (Suprasil 312) discs was also assessed before cleaning. A typical interferogram is shown in Figure 3.

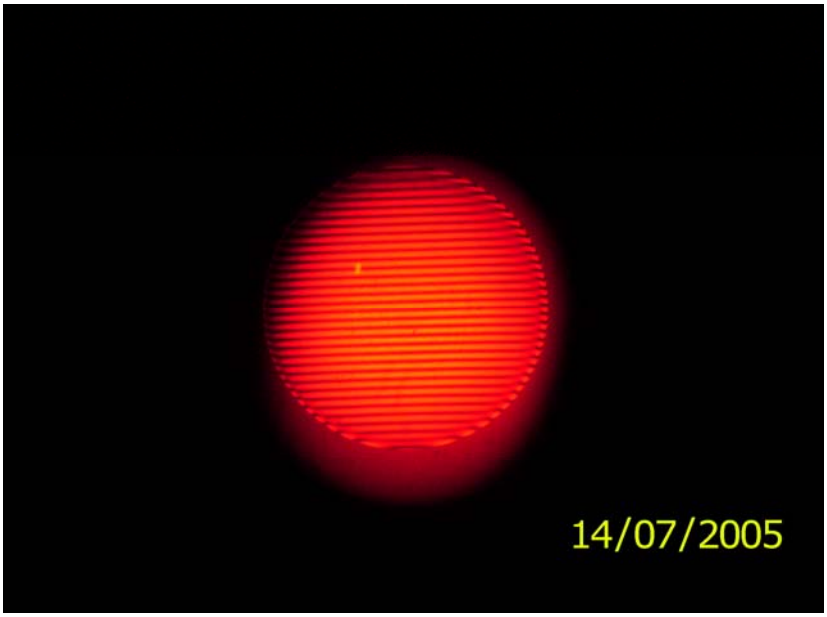


*Figure 3 Interferogram indicating flatness of a typical received Suprasil 312 disc from Vendor 'A'.*

The global flatness of all ‘as received’ pieces was considered acceptable for bonding.

A flat was also inspected after being cleaned according to the Advanced LIGO bonding procedure[2] in order to check that the surface abrasion associated with cleaning the surface using cerium oxide paste had not degraded the global surface flatness of the sample (see Figure 4). No significant change in flatness was observed.

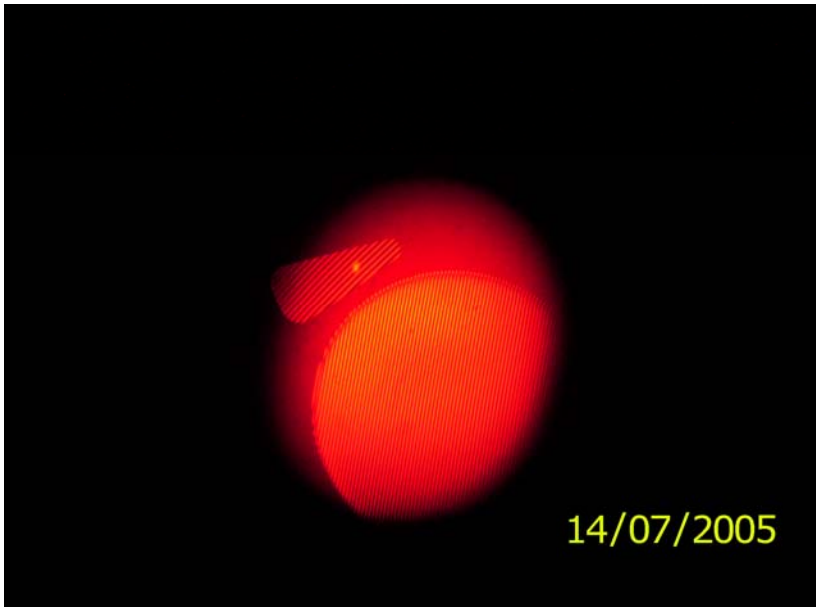


*Figure 4.* *Interferogram indicating flatness of silica flat after cleaning procedure using cerium oxide. Note the ear shown has not been cleaned.*

The remaining ears and flats were then cleaned using the same procedure.

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 showed slight bubbles – coloured fringes were still visible after a few minutes – this is fairly common and not of concern as the fringes disappear during bond curing.

*Additional Comments:*

The ears had an acceptable polish on the bonding surface with specified flatness 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 spread out correctly from above. However inspection could be carried out through the disc/flat after 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.