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Early tests on a bonded ear / welded fibre assembly

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## 1 Introduction

This short technical note provides a record of an early load test performed on a simple bonded ear/welded fibre assembly. The ear used in the tests was a “preliminary test ear” (i.e. the first design of ear prototyped for potential application to Advanced LIGO). This ear was fabricated with only a fine ground finish. Hence flame polishing was used in the region where the horn met the main body of the ear to reduce the local stress levels due to micro-cracks in this sensitive region.

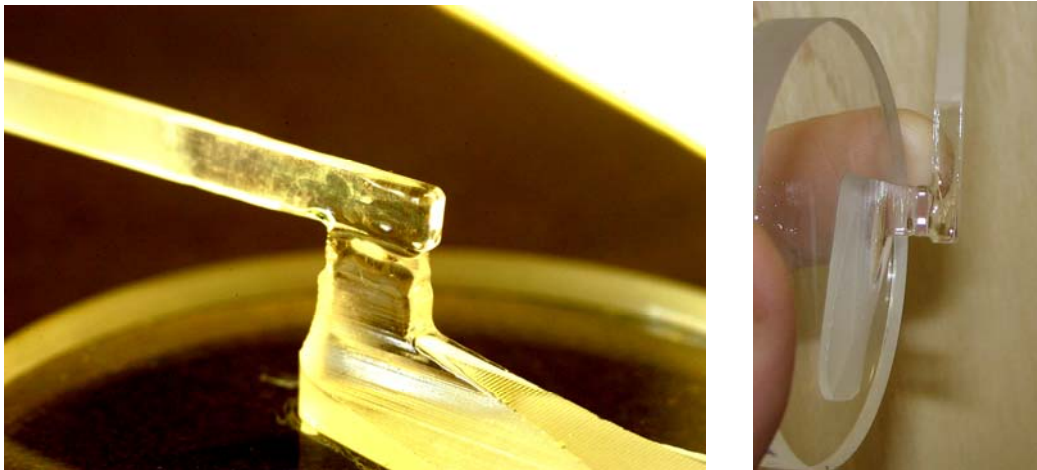
*As a result of this early investigation both the ear design and surface finish requirements were refined to reduce the resulting stress levels within the ear under loading.*

## 2 Test Description

Preliminary test ear SN0003 (drawing number D050168-06) of Suprasil 2A was bonded to a Suprasil 312 disk on 5<sup>th</sup> July 2005 <sup>1</sup>.

All welding, fibre pulling and load testing reported here was performed by A. Heptonstall between 16<sup>th</sup> and 24<sup>th</sup> Jan 2006.

A 75 mm long silica rod of cross-section 3 mm x 1.5 mm was CO<sub>2</sub> laser welded to the horn of the (partially flame-polished) preliminary test ear (see Figure 1a & 1b).



*Figure 1a & 1b Laser welded rod (3 mm x 1.5 mm) (16<sup>th</sup> Jan 2006) on Preliminary Test Ear SN0003 bonded to Suprasil 312 disk (bonded 5<sup>th</sup> July 2005. Note that the ear has been partially flame polished in region of the horn/main body interface.*

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<sup>1</sup> T050209-00-K “Bonding & visual inspection of preliminary test ears (serial number 0001 - 0004)”, S. Rowan, J. Hough and C. A. Cantley

On the first loading attempt the silica rod broke just below the horn due to angular misalignment of the loading axis with the rod axis. A replacement rod was then flame welded to the remaining laser welded rod stump. This formed a 'bond - laser weld - flame weld' assembly.

This assembly was clamped and loaded to 12.5 kg. This hung successfully for a few hours (see Figure 2a & 2b).



*Figure 2a & 2b 12.5 kg suspended from laser welded rod on bonded Preliminary Test Ear SN0003 (20<sup>th</sup> Jan 2006)- right hand side of photo*

However, after a few hours the epoxy/clamp arrangement which allowed the 12.5 kg mass to be clamped to the rod end failed (load slipped off). At this stage the silica bond and silica welds were inspected and found to look uncompromised.

A silica fibre was then laser pulled (25cm long with approx. 250 micron diameter (end/stock diameter 1.5 mm)). This was then flame welded at the location of the second weld (old flame weld). The assembly was then loaded to 4 kg. However the fibre failed at thinnest part of neck.

This process was repeated and the top (laser) weld to straight (horn and first rod) section was gently softened using the flame.

This assembly was then used to suspend 2.5 kg. When the load was increased to 4.5 kg failure occurred within the body of the ear itself (see Figures 3a, 3b, 4, 5a & 5b).

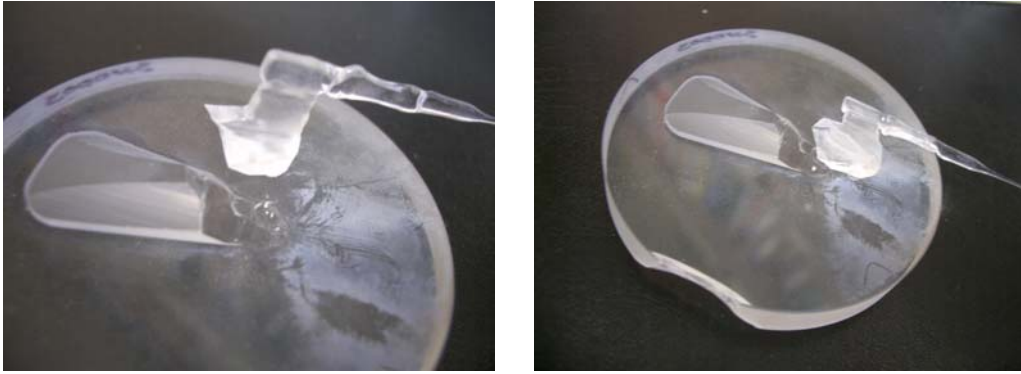


Figure 3a & 3b Failure location



Figure 4 Failure location in ear showing torn silica – bond does not appear to have been compromised.

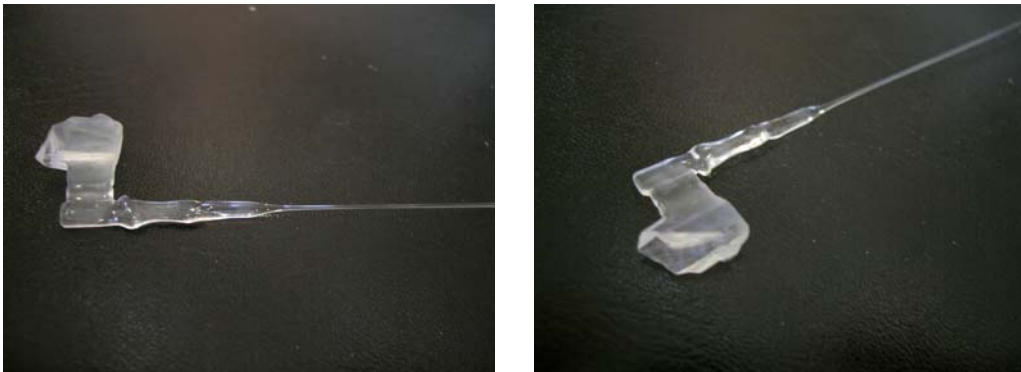


Figure 5a & 5b Failure location in welded horn

Failure occurred within the preliminary test ear at the edge of flame polished region. This is where largest thermal stress from polishing would occur. Couple this with the rough finish at this non-polished location on the ear and this would explain why failure has been initiated at this particular location. This is closer towards the toe than the horn/ear interface where the largest stresses would

occur due to geometrical considerations. This sharp radius where the horn leaves the main body of the ear is flame polished hence resulting in lower stresses at this location.

There was no obvious sign of bond degradation, the silica material of the ear had been fractured and torn apart.

### 3 Conclusion

The first loading test at 12.5 kg exceeded the Advanced LIGO operating load of 10 kg. There may have been some damage left from the first test that encouraged the later failure. This work highlighted the importance of the ear surface finish and ear geometry to reduce stress concentration. The 12.5 kg loading test was conducted on a bonded/welded system as part of a continuing series of tests.

*As a result of this early investigation both the ear design and surface finish requirements were refined<sup>2</sup> to improve the stress levels within the ear under loading.*

*If required light flame polishing could be considered to further improve the surface finish of the ear with a view to further reducing stress concentration levels. However caution should be applied in doing this due to the resulting thermal stresses within the ear.*

*The baseline design is to achieve the required ear surface quality during fabrication and to avoid the use of flame polishing.*

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<sup>2</sup> D060055-02 “Refined Ear (Type A)” and D060056-02 “Refined Ear (Type B)”