Development of tools for GEO600 test mass suspension repair.

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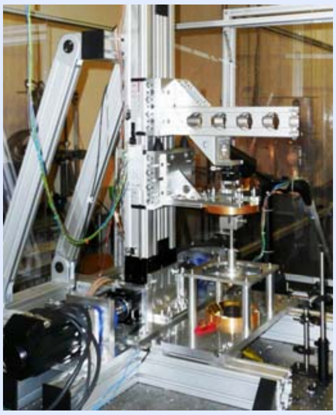
Introduction

The GEO600 detector employs a triple pendulum suspension with a quasi-monolithic lower stage to minimise suspension thermal noise. Fused silica fibres which are welded to silica ears are used to suspend the test masses. The detector is currently being upgraded to GEO-HF which will focus primarily on frequencies above 500 Hz [1]. During this upgrade there is a risk that the suspension fibres might be damaged while optics are replaced in the vacuum tanks. A robust procedure for repairing the suspensions needs to be in place in order to minimise the downtime of the detector. The Glasgow group has gained significant experience over the past decade in developing monolithic suspensions for both the GEO600 detector and the Advanced LIGO (aLIGO) project [2]. An additional opportunity also exists to re-optimise the GEO suspension design utilising the techniques gained from the aLIGO system.
The repair scenario will involve fibers fabricated at University of Glasgow using the CO_2 laser pulling machine (figure 1) [2]. Fibers will then be transported to the GEO site in a sealed enclosure and welding will take place with a H_2-O_2 flame (identical to the original GEO suspension).

Fabrication of silica fibres



The old GEO suspension incorporates flame pulled fibres which are difficult to fabricate whereas laser-polished pulled fibres are stronger and far more accurate in dimension. These fibres (figure 2b) are highly reproducible having a very short neck length leading to a smaller variation in the bending point (typically 2 mm between different fibres), thus giving a better control of suspension system.

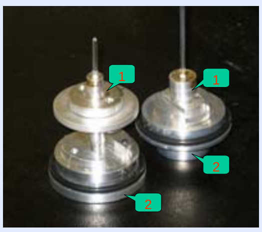
Figure 1: CO_2 laser pulling machine facility at Glasgow.

Figure 2 (right). A fibre (a) fabricated for the original GEO-600 suspension (using flame on a stock with 5mm diameter) in comparison with a fibre (b) pulled using the laser pulling machine from a 2mm silica stock.

Fibre transportation containers

To ship the silica fibres for long distances we fabricated a few special containers. A thick-walled plastic tube of diameter 5cm has been employed as a stiff frame of enclosure and a protective screen at the same time. An aluminium "fuse-end", that is glued to the 2 mm stock on the fibres ends by a thermoplastic cement *Lakeside® N_0 70C* (see figure 4), was fastened to an end-cup of the plastic tube with a tensioning screw. The fibre can be installed into the tube (both are situated vertically) without touching the wall. The container can hold the fibre with a tension ≈ 1 kg. This keeps the fibre aligned in the centre of the stiff tube immune to external vibration.

Figure 3. The fibers transport containers made from a polycarbonate tube.



In addition, the construction of the enclosure allows a proof test the fibres while they are still within the container (see figure 5).

Figure 4. The aluminum "fuse-ends" glued to 2mm silica stocks (1) were fastened to the end cups (2).

Figure 5.The fiber is tested (in situ) to prove its durability; the bottom "fuse-end" is not fastened to the polycarbonate tube; the container is used as a protective shield here.

Test shipment of fibres

To examine the design reliability we shipped fibers from Glasgow to Hannover twice. The shipment was provided by a commercial courier service and in a passenger accompanied luggage. On arrival the fibers pulled in Glasgow were strength tested at the Albert-Einstein Institute in Hannover. The fiber of diameter 176 μm was broken at 11.7 kg which corresponds to a breaking stress of 4.8 GPa. This is a typical strength of CO_2 laser-pulled silica fibers.

Tooling development for welding silica fibres

Any future suspension work at GEO will utilise flame welding. This is different to the case of the aLIGO suspension which incorporates laser welding. In GEO-HF laser welding cannot be used to due to lack of the necessary laser facility at the GEO site. The welding of silica fibres to the silica ears will require a new set of tooling which has been inspired (a miniaturised version) by the tooling used for Advanced LIGO suspension. The new set of tools includes a fibre cutter (figure 6) to get a fibre of desired length and a fibre holder with linear x-y-z stages (figures 7,8). The fibre holder can be scaffolded onto the metal frame of the suspension (figure 8).

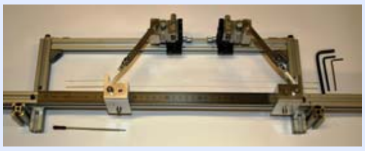


Figure 6: Fibre cutter / holder having three x-y-z stages for accurate adjustment while welding

Figure 7.
During welding, the fibre is held in position by tweezers with ceramic tips.
To keep the surface of the fiber pristine the tweezers grip the fiber by the 2mm stock.

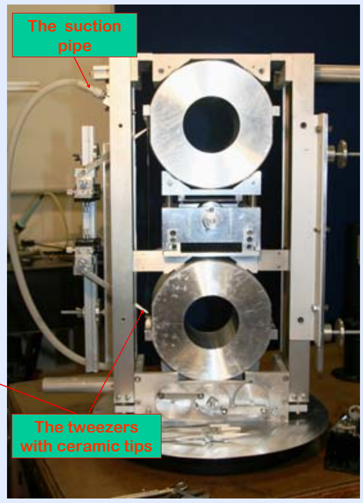


Figure 8 (on the right): GEO prototype suspension with metal masses (5.6 kg). The ear holder is bolted in place and is set up for flame welding of silica fibres. The ears are glued to an aluminium holder by an epoxy Araldite 2012 or by heat-proof adhesive Resbond 989F.

A metal heat shield will be placed behind the ears (figure 9) to protect the surface of silica test mass from silica vapour deposition. A suction pipe will also be used to extract silica vapour [4] while flame welding the fibres (fig. 7-9).

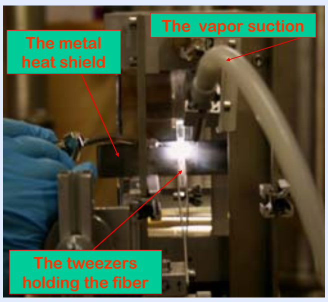


Figure 9. The test welding of the fully monolithic silica suspension.

Figure 10. The bonded silica ear with welded fibers.

Test welding using silica fibres and ears was performed on aluminum test masses first, and upon its success, monolithic silica suspensions were then fabricated in Glasgow (see welds and the overall view in figures 10 and 11). This procedure will ensure that the GEO-HF detector can operate as part of the worldwide network in the future.

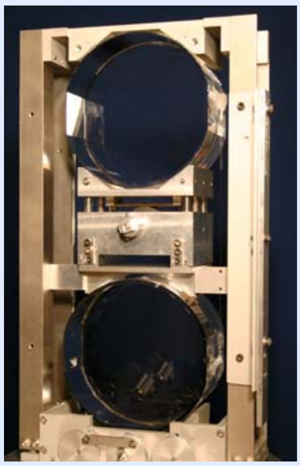


Figure 11. The GEO test mass (the replica) suspended on the laser pulled silica fibers by flame welding technique.

Acknowledgements

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1. H. Grote, Class. Quantum Grav. 27 (2010) 084003 (9pp)
2. A. Heptonstall et al, Rev. Sci. Instrum. 82, 011301 (2011)
3. K. Tokmakov et al, the poster report on the Amaldi 8 Conference, New York, 2009; available as LIGO-G0900586.