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New mirror support point design.

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1 Introduction

The mirrors of Ad-LIGO are presently designed to be suspended with fibers or ribbons welded to ears. The Ears are to be fastened, by means of silicate bonding, to two flats machined on the sides of the Ad-LIGO mirrors. The fibers would then be welded in situ to the ears. Both processes may generate problems of cleanliness on the mirror surfaces, and present challenges of mechanical precision in their implementation.

Replacing mirror suspensions in this scheme would involve in situ cutting the tips of the FS noses, and laser re-welding, and therefore be a major enterprise.

The noses stick out of the mirror profiles, and are therefore comparatively vulnereable in transport and installation.

If one wants to correct the gravitational sag of the mirrors, as well as the deformations due to the stress in the coatings, there is a need to suspend the mirrors during metrology in the same way that they will be supported in operation. This means that the mirrors should be suspended from the ears also during the metrology steps before the correction coating. This would require the assembly of the ears before coatings, and the ears would produce problems with correct clamping and heat sinking of the mirrors during the hot evaporation process.

Additionally there is the philosophical point that silicate bonding on the mirror side flats would be working under pure shear stress, which should be avoided whenever possible, and there are still lingering doubts about the reliability of silicate bonding on a large statistics of pieces.

Last, the machining of the two flats foreseen for the silicate bonding is reasonably extensive (20% of the outer surface) and touches the front and back surfaces of the mirrors.

2 Studying alternatives

One way to solve these problems would be to cut two smaller slots, illustrated in figure 1, removing less material and machining only about 20% of the surface than in the case of the flats, 4% of the total external surface. The transversal cut would produce a “shelf” from which the mirror can be supported in a shear free configuration (only compressional stress in the contact areas.

The vertical cut would be needed to allow the passage of the suspension fibers or ribbons. The depth of the cut would be the same than in the case of the flats.

The attachment of the fibers would be made with fused silica “anchors” touching on the mirror shelves on 2x2 mm small spots. The fibers or ribbons would be pre-welded to the anchors in the lab, posing no threath to pollute or damage the mirror surface.

The rubbing noise at the contact points can be eliminated with sub micron thick Indium gaskets. One could naively scale the thermal noise contribution of these joints assuming a Q factor of one for the Indium, 1 Billion for the fused silica and weight the contributions by the relative volume factors, $4x4\ 10^{-12}\ m^3$ for the four gaskets and 0.018 m^3 for the mirror body. Even in these pessimistic assumption the contribution of the gaskets would be equal or less than of that of the mirror’s bulk. One should then take into account that:

- the Q of Indium films is far from one,

- Indium under such hydrostatic pressure will flow away from the “mountains” on the contacting parts and the actual points of contact would be between FS and FS
- because of the Levin theorem, and because the gaskets are farther from the mirror surface than the bulk of the mirror, losses in that region would have an effect on thermal noise several times less than equal losses in the bulk near the mirror surface (not counting the coating losses which are even more important than the bulk ones)

With this in mind one can realize that the compressive Indium bonding on small surfaces can be a safe technique from the point of view of mirror suspensions.

Braginsky reports that this tecnique can be used to eliminating all rubbing noise without introducing significant dissipation noise.

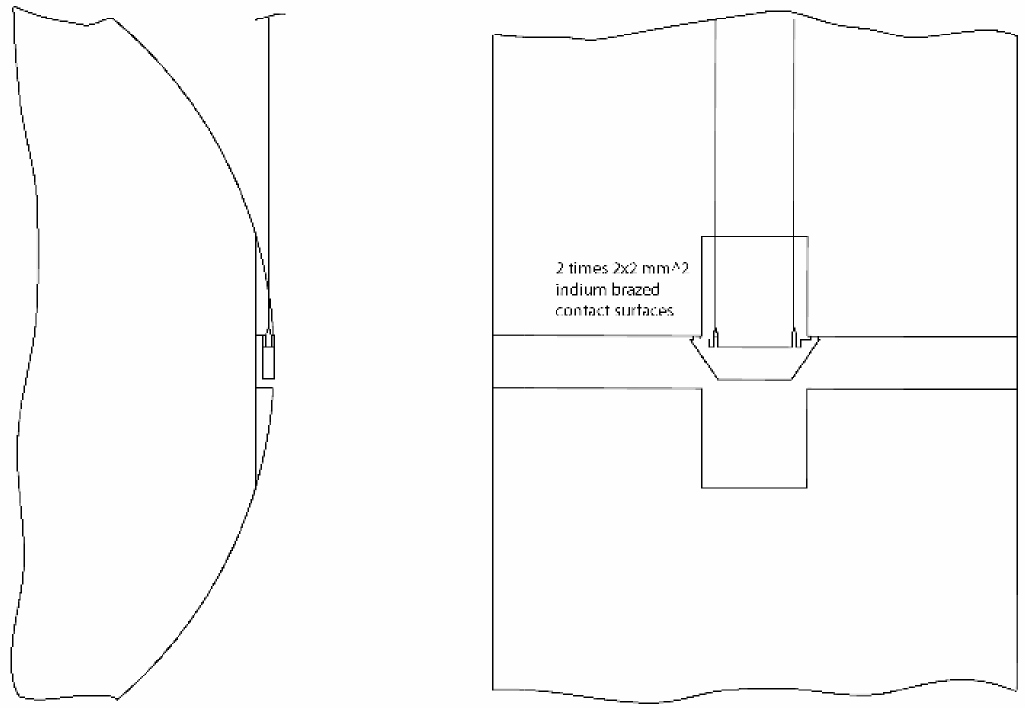

Figure 1: schematics of mirror suspended from “shelves” machined on the mirror side.

Obviously the same technique would be used to attach the fibers or ribbons to the intermediate mass above, thus possibly offering a natural transition point between fused silica and metals.

The most important important advantage of this technique is then that it would allow for comparatively easy implementation and substitution of the suspension fibers, without entailing in-situ machining and welding.

Following the initial idea we contacted John Tardif at Waveprecision to discuss the idea. Together we arrived to two improved designs.

He suggested that, instead of cutting the entire horizontal slot, we can simply plunge a 150 mm diamond coated grinding disk in the place where we need to attach the anchor. The idea is illustrated in figure 2. The advantages of this scheme is that less material is machined and the machining remains at all times far from the mirror optical surfaces.

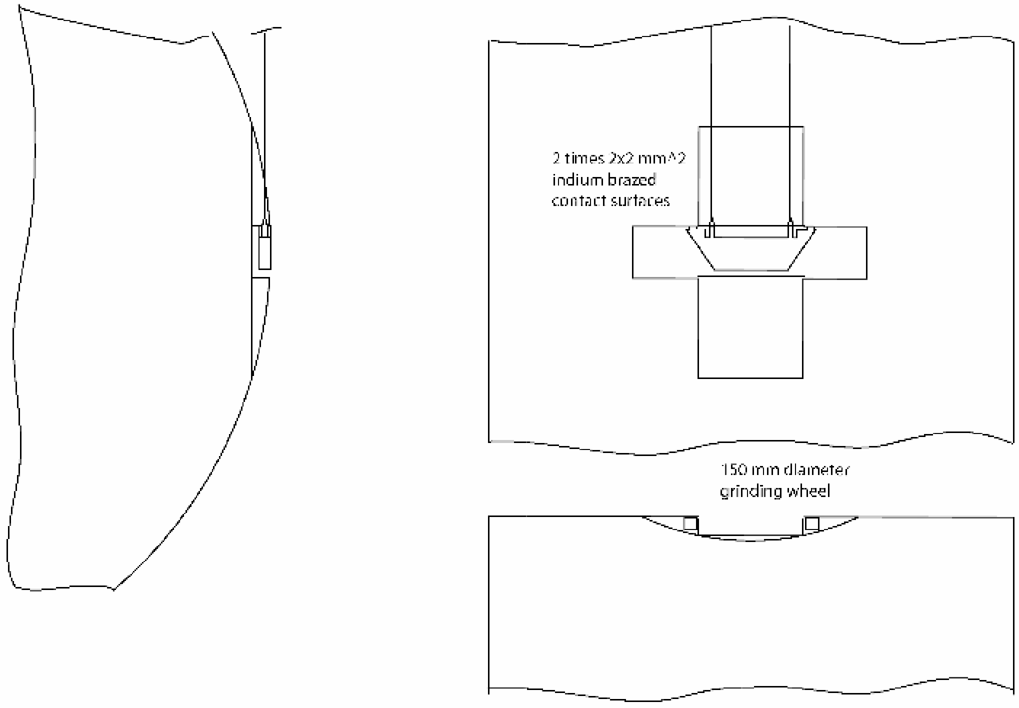

Figure 2: As in the preceding case the vertical slot is ground out first. The horizontal slot is then obtained by plunging a 150 mm diameter cutting wheel in the mirror side. Less material is machined away from the bulk but some gouging is made in the vertical slot bottom surface. A possible disadvantage is that the grinding wheel enters the vertical slot on one side and exits it at the other side. Some chipping is possible as the wheel enters the vertical slot. Number 16 finish of the support surface can be achieved before polishing.

The other scheme is to apply two smaller cuts, plunging two times with a 30 mm diameter diamond-coated grinding wheel on the two sides of the vertical slot. This geometry, shown in figure 3, grinds away even less mass from the bulk.

An additional advantage of double plunging is that one could perform one plunge with the wheel turning clockwise and the other plunge counterclockwise. This is a possible advantage over the scheme of figure 2 because in that scheme a large diameter grinding wheel plunges across the vertical slot. On the side where the wheel leaves the perpendicular surface of the slot it might chip off material from the edge. Doing plunges with reverse directions, one can work with the tool always rotating into the sharp perpendicular corner and minimize the risk of chipping. Also there is no gouging of the surface of the vertical slot by the double plunging process.

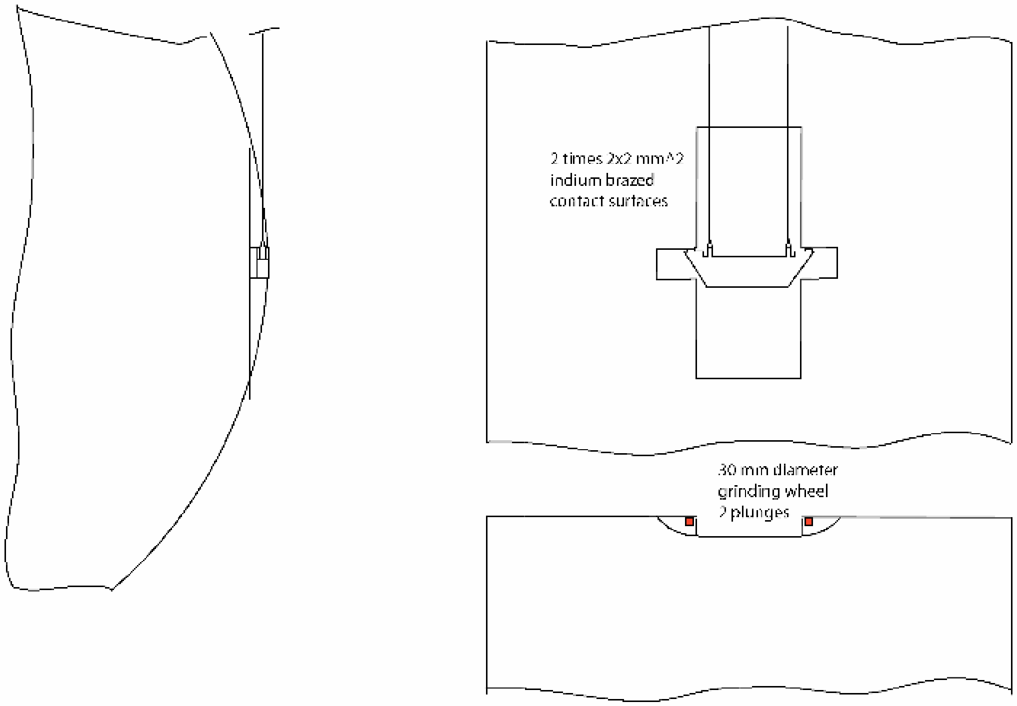

figure 3: The support surfaces for the anchors are obtained using two separate plunges of a smaller (30 mm diameter) grinding wheel. The amount of machined off material is minimized. If edge chipping turns out to be a problem when the grinding wheel leaves the slot, grinding with opposed rotational direction of opposing sides can be used to avoid this problem.

The process sequence would be as possible

- polish the outside surface,
- machine the vertical slot and polish it with felt-bobs or polishing wheels,
- perform the plunge cuts and polish it with polishing wheels of same shape..
- polish the back and front optical surfaces would be done only after all machining is finished.

3 The anchors and fibers

In the proposed mirror suspension geometry the anchors and fibers (or ribbons) are machined, assembled and welded in the laboratory, far from the mirror and the difficult vacuum chamber environment. The anchors are similar in complexity to the ears. Of course careful dimensioning must be done and tested in Finite Element analysis and in test suspensions to aliminate bothersome resonances and flexing. There appear to be no fundamental problem in their machining and construction.

The developments made so far, to perform laser welding in situ, will work even better in the more controlled laboratory conditions and result in better mechanical precision.

There is an additional advantage that each anchor and fiber unit can be individually tested and, if necessary heat treated to anneal out the welding stresses before assembly on the interferometer.

Advanced design units (for example ribbons) can be implemented relatively easily.

4 Conclusions

The new proposed mirror suspension geometry eliminates any shear force in the contact areas, completely eliminates the need of silicate bonding (no liquids and no potentially dangerous water vapour involved) and replace it with pressure bonding of Indium to FS (possibly treating the contact surfaces with Ni flashing (100 Angstrom thick) and thermally assisting it (50-100^{o}C)) over much smaller surfaces. In situ suspension replacement are much easier, involve no welding and machining, and are made with laboratory pre-welded and characterised fiber-and-anchor structures. The support surfaces are fully recessed, therefore less exposed to damage and not bothersome during the front surface polishing and coating steps. Smaller amount of material (15-20% than in the present design) is machined off and less external surface is involved. The geometry lends itself to equal suspension of the mirror during characterisation and operation.

Replacements in the vacuum chamber of the suspension fibers should be substantially speedier, thus reducing the exposure time to ambient humidity and pump-down times, while at the same time using lab prepared spare fiber units, supposedly of even better controlled mechanical quality.

We believe that this scheme has the potential of replacing with advantage the present mirror design scheme, and that machining tests of reject fused silica parts should be performed to try out the viability of this scheme and find out its problems.