Suspension systems for the AEI 10 m prototype

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Introduction

The AEI 10 m prototype interferometer, in Hannover Germany, aims to undertake experiments to investigate improving gravitational wave detector sensitivity through studying quantum mechanical effects of photon shot noise and radiation pressure noise on macroscopic (100 g) mirrors. Figure 1a shows a full build of the 10 m Prototype suspension using all metal suspension elements. Figure 1b shows closer views of different elements of the suspension

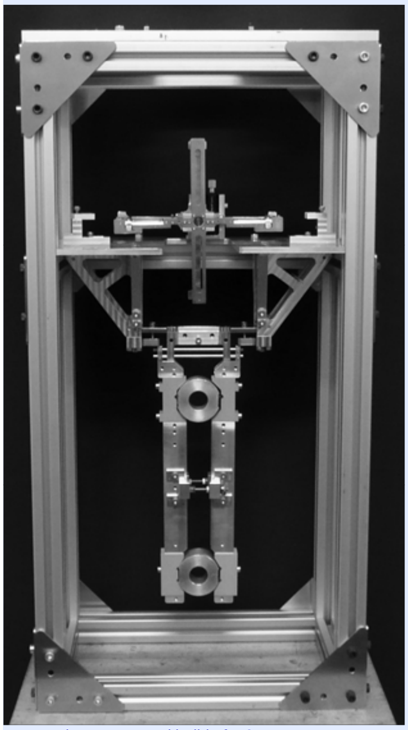

Figure 1a. Metal build of 10 m Prototype suspension.

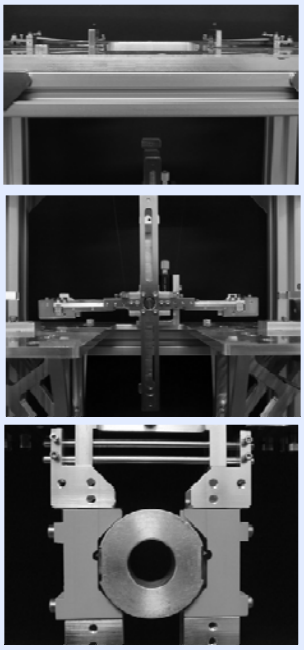

Figure 1b: Top; top stage suspension blades.

Middle; upper cross mass suspended from top stage wires.

Bottom; metal penultimate mass suspended from lower blades on the cross mass.

Fabrication of silica fibres

Silica fibres will be produced by CO_2 laser pulling from thick silica rods. The fibres are required to be ~20 µm diameter in order to keep the vertical resonant frequency of the suspension at low enough frequency, so this noise peak does not impinge on the measurement band of 30 Hz to 1 kHz.

In order to achieve this very small diameter, the silica rods are pulled first down to approximately 400-500 µm diameter, with the thin fibre then being pulled from this. This provides a suitable diameter at the fibre end to weld to the ears, as shown in figure 2. Fibres as thin as 15 µm have been demonstrated using this technique.

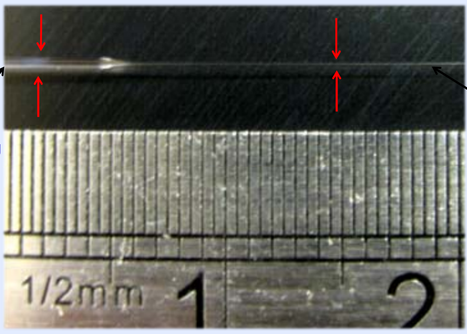

Figure 2. 20 µm diameter laser pulled thin fibre.

Isolation - Blade springs

The blade springs used for the upper stages of the vertical isolation will be made from maraging steel. Figure 3a shows an unloaded lower blade. Due to the extremely small test masses the blade springs are very much smaller and thinner than for previous experiments and are only ~60 mm long with thickness of 0.3 mm. ANSYS FEA software was used to validate the mechanical performance of the blade design. This includes modelling the resonant frequencies of the blade which show a vertical bounce mode a 2.9 Hz and the first internal mode at 369 Hz. Figure 3b below shows the frequency response for a blade loaded with 100 g, frequencies were measured at 2.5 Hz and 371 Hz.

Figure 3a. Photo of delivered 0.3mm thick 60 mm long maraging steel lower suspension blade, with root width 5mm and radius of curvature 40.58mm. The thickness was achieved by using a cold lapping process rather than the more common grinding to avoid burning the material.

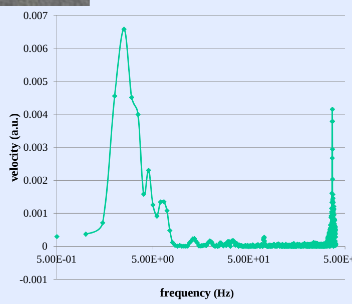

Figure 3b. Frequency response of real blade showing response at ~2.5 and 371 Hz for a blade loaded flat with 100 g. Frequencies were measured using a Polytec laser vibrometer.

Laser welding fibres

Fibres will be CO_2 laser welded onto fused silica ears on the test mass sides, in order to provide an ultra low thermal noise quasi-monolithic lower stage. Initial weld tests have been done, showing the feasibility of this technique for very small scale glass components.

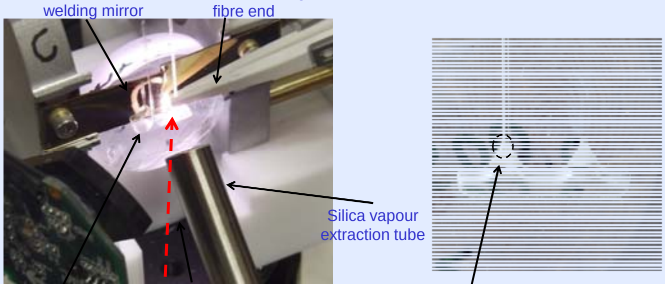

Figure 4. Laser welding setup for thin fibre suspensions.

Welding is performed with a CO_2 laser beam focussed to approximately the diameter of the fibre end (~0.5mm). The fibre is held in zirconia tipped tweezers and a gold coated mirror is placed behind the ear horns to provide heating to the back surface of the weld (figure 4).

The build process has been tested on a full metal suspension and plans are moving forward for a test suspension using fibres welded to ears attached to metal masses. This should lead to a full monolithic test assembly being produced in the very near future.