Progress Report on Suspensions from GEO600 group: August 2002 – February 2003, for LSC

Suspension developments relevant to Advanced LIGO.

- Proposal for substantial funding towards suspensions, related electronics and sapphire blanks for Advanced LIGO has been submitted to the UK Particle Physics and Astronomy Research Council (PPARC) in June 2002 (GEO600 Glasgow plus Rutherford Appleton Laboratory and University of Birmingham). This has been approved by the PPARC Science Committee (February 2003) and now awaits formal ratification by PPARC Council.

- Installation of fused silica suspensions in GEO600 (beamsplitter and two near mirrors) is complete (December 2002) (GEO600 team).

- Work is now complete on the prototype quadruple suspension at MIT. (Mittleman (MIT) with Torrie (Caltech) and N Robertson (Stanford))

- The suitability of ribbons for suspending the test masses in Advanced LIGO has had preliminary testing with 20kg masses suspended from two ribbons for several weeks. Work is now progressing on the suspension of 40 kg from four ribbons as per Advanced LIGO requirements (Heptonstall and Cagnoli).

- Design work and experimental test of methods for adjusting blades in suspensions and analysis and testing of blade deflection continues. A library of blade clamps has been developed to allow fine-tuning of loaded blade deflection. A comparison between theoretical (ANSYS model) and blade performance has been completed and the blade fabrication method are being revised to minimize discrepancies. Improved design of blade wire clamping method underway (Jones, Plissi, Perreur-Lloyd, Cagnoli, Elliffe, Cantley + Torrie (Caltech) + Rutherford Appleton Lab).

- Work on design and fabrication of electronics and coil former assemblies for controls prototypes at Caltech and LASTI is ongoing. (Ward, D Robertson, Jones, Perreur-Lloyd, Elliffe, Grant + Torrie et al (Caltech))

- Work on eddy current damping at Glasgow is almost complete. The GEO600 prototype triple pendulum has been re-adjusted to minimize cross-coupling effects. Vertical and longitudinal damping has been investigated and initial results plus comparison to model are promising for damping of triple pendulums. The linearity of the damping effect has been tested using a smaller magnet array (Plissi, Grant, Jones, Cantley + Torrie (Caltech) and N Robertson (Stanford))

- The detailed design of the modecleaner triple suspension, the first controls prototype for LASTI, is complete at Caltech, with input from N Robertson (Stanford) + GEO600 Glasgow. Detailed design for the recycling mirror

suspension is underway (Plissi, Cantley, Perreur-Lloyd, Torrie (Caltech) + N Robertson (Stanford)). Work on quadruple suspension design is ongoing with the Simulink model, taking into account recommendations of document on cut-off frequency. (N Robertson (Stanford))

- Experience on various CAD and finite element packages is continuing to develop to allow easy transfer of information between Glasgow and LIGO. These include SOLIDWORKS, E-drawings, 3D TeamWorks, ALGOR and I-DEAS (Jones, Perreur-Lloyd, Cantley, Elliffe working with Romie and Torrie (Caltech))

- Preliminary work has begun to investigate the use of silica blades for enhanced vertical isolation in the final pendulum stage. Preliminary loading tests have been carried out on basic silica blades and protective abrasion resistant coatings for the blades are being investigated (Cagnoli, Heptonstall, Plissi and Cantley).

- Violin and pendulum Q measurements are in progress to characterize the silica ribbon suspensions in full and to tie the fundamental violin mode Q with the pendulum Q (Cagnoli, Heptonstall and Strain).

Materials developments relevant to Advanced LIGO

1. Investigation of losses of dielectric mirror coatings, in collaboration with Stanford University, Syracuse University, MIT, and Hobart and William Smith Colleges. (Sneddon, Crooks, Cagnoli, Hough and Rowan).

- We have extended our investigation of the mechanical loss factors of SiO_2/Ta_2O_5coatings, and have:

  (a) completed a draft publication summarising the outcome of these experiments, (to be submitted to Classical and Quantum Gravity*) S. Penn, P. Sneddon, H. Armandula, J.C. Betzwieser, G. Cagnoli, J. Camp, D.R.M. Crooks, M.M. Fejer, A.M. Gretarsson, G.M. Harry, J. Hough, S.E. Kittelberger, M.J. Mortonson, R. Route, S. Rowan, C.C. Vassiliou, "Mechanical Loss in Tantala/Silica Dielectric Mirror Coatings,"*

  (b) analysed the frequency dependence of coatings containing different proportions of SiO_2/Ta_2O_5 .Our analysis suggests that there is a shallow frequency dependence to the coating mechanical loss, with the loss improving towards lower frequency. Modelling this loss as 'intrinsic' dissipation associated with the individual coating materials suggest the frequency dependence is associated with the SiO_2 present in the coatings.

- Measurements of the loss factors of silica samples coated with Al_2O_3/Ta_2O_5, and SiO_2/Nb_2O_5 coating respectively have been carried out and we are in the process of measuring samples coated with SiO_2/Al_2O_3.

- A figure of merit for the expected thermal noise arising from the intrinsic dissipation of coatings of different materials has been calculated, and the importance of the relative material properties, in particular the Young's modulus, of the substrates and coatings has been identified. This, along with our current measurements, suggests that the most appropriate coatings are, for a fused silica substrate SiO_2/Ta_2O_5, and for a sapphire substrate Al_2O_3/Ta_2O_5.

2. Development of a prototype all-fused-silica pendulum suspended using a fused silica ribbon suspension has been carried out. This is currently installed in the pendulum Q testing facility in Glasgow, and measurements on the pendulum mode Q factor are currently underway (Heptonstall, Cagnoli, Hough and Strain)

3. Investigations have continued on hydroxy-catalysis bonding techniques. We have carried out investigations into modifying the technique to extend the initial setting time of the bond in a controllable way, to allowing for precision positioning of pieces. (Elliffe, Reid and Hough.)

4. Analysis of the loss factors of hydroxy-catalysis bonding material used to bond silica and sapphire substrates has been completed, and a draft publication produced, (to be submitted to Classical and Quantum Gravity: *P.H. Sneddon, S. Bull, G. Cagnoli, D.R.M. Crooks, E.J. Elliffe, J.E. Faller, M.M. Fejer, J. Hough and S. Rowan, "The intrinsic mechanical loss factor of hydroxy-catalysis bonds for use in the mirror suspensions of gravitational wave detectors,"*

5. We have ordered and received parts to allow the construction of a heavy glass mass of 25cm diameter to form a prototype intermediate mass for Advanced LIGO. (Cagnoli and Hough)

Other research developments relevant to Advanced LIGO

Work on an experiment to allow direct measurement of the off-resonant thermal noise of the pendulum mode of a suspended silica mirror continues at Hannover. The experiment has been redesigned to achieve higher moments of inertia for the masses of the different pendulum stages. The changes especially reduced the resonance frequencies of the three rotation modes of the masses, which significantly reduces the seismic coupling at higher frequencies. Another vertical isolation stage has also been included. However the locking process of these new pendulums causes problems, as these new masses have a number of internal resonances in the control band. Future development depends on the success of the current experiments and might lead to another redesign of the different pendulum stages. (Leonhardt et al.).

Participation

Participation over period August 2002 to February 2003 was as planned.