Response from SUS team to questions raised by the review committee for the Ribbon/Fiber/Ear/Bonding PDR concerning the design of the modecleaner suspension.

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T060014-00-R

1) How much loss from friction between wire loops and the optic is being assumed for the MC suspension? Where does this come from? How well coupled are these plans and what we are learning from initial LIGO suspensions?

In our document "The Use of Steel Wires for the Advanced LIGO Modecleaner Suspensions" T060008-00-R, we have considered both the case where there is no significant loss from friction, where we assume the intrinsic material loss is 2×10^{-4}, and where friction raises the loss by a factor of 10. We understand that from the measurements of violin mode Qs in initial LIGO that the value of the largest of those Qs (150,000) is in agreement with expectations of the intrinsic material loss in wire plus loss due to the thermoelastic effect and the dilution factor as expected. (ref Fritschel et al, T050252-00-1). However since some variability of Qs was seen, we also consider the implications of taking a value for the total effective loss of 2×10^{-3} (excluding thermoelastic).

We are planning to investigate alternatives to wire loops as part of the quadruple suspension design at its penultimate mass, (as mentioned in the responses to the ribbon/fibre/bonding questions G050558 page 7) and such work could also be applied to the modecleaner suspension.

2) The planned wires seem very small and highly stressed compared to initial LIGO suspensions. How near the breaking stress are they planned to be? Are there concerns here?

The current proposal is to use wires stressed to the same level as in initial LIGO. See T060008-00-R. We are not aware that wires stressed to this level have concerns.

3) Can the decision to use wire suspensions in the MC be postponed until more initial LIGO research is done?

The detailed design of the noise prototype modecleaner suspension is due to start early in 2006. It would be preferable that the decision has been taken by that time.

4) Is there a requirement on violin mode frequency equilization? What sets this?

To date no requirement has been given to the SUS team on this. Details of requirements as currently set are given in T010007-02 "Cavity Optics Suspension Subsystem Design Requirements Document" M Barton et al.

However we have inquired from Peter Fritschel what his view is on this matter. His response (email to NAR on 23rd October 2005):

"I'd say that for a given optic, the violin mode eigenfrequencies should be matched to within a couple of percent. We probably need to notch out these frequencies in the feedback to the MC length, and don't want to have to make too wide a notch to preserve phase margin.
From one optic to another the eigenfrequencies could be more spread out, say within 5%."

Peter asks if we think this is feasible. This is our response:

i) Fused silica fibres.

See T050215-00 "Monolithic stage conceptual design for Advanced LIGO ETM/ITM". Section 4.4. states, from consideration of allowable error in bounce frequency, AdvLIGO requires dimensional tolerances of +/1.9% whilst GEO achieved +/- 2.1%. Experimental work is being done on the reproducibility of fibre and ribbon parameters, and it is expected that using the laser-pulling and welding machine which is currently being developed, the reproducibility will be better than obtained for GEO.

Regarding the violin mode spread achieved in GEO, information can be found in Stefan Gossler's thesis, as below.

Section 5.2. Requirements for Inboard Suspensions
requirements for violin modes from consideration of servo-control states
"all frequencies within one mode fn (i.e. eight frequencies per mode for the two suspensions) within +/- 5% for the first two modes f1, f2"
see also Section 5.4.5 - treatment of fibres before welding
and
Section 5.4.6. - In-situ tuning after welding
Section 5.6. measured spread in violin modes on inboard suspensions
f1 = +/- 3.86%
f2 = +/- 4.86%
thus meeting GEO requirements.
Note however that the GEO experience may not be directly relevant since some of the tuning was done by application of Teflon for damping, and it is not clear if we would use this in Adv. LIGO MC suspensions.

ii) Steel. This does not seem too challenging. For a 2% spread (or 12 Hz in 600 Hz) we are looking at a length variation of less than 2% in 22 cm, i.e <4.4 mm assuming equal tension. The wire loops are produced in a wire jig which leads to repeatability which is much better than 1 mm. We should also consider variations in the diameter of 'as bought' wire. For the proposed diameter (120 micron or 4.7 thou) the standard tolerance from California Fine Wire Co. is +/-1/10 thou or +/-2.1%. This should be acceptable, since the tolerance on smaller lengths is likely to be better. We also note that the company can provide tighter tolerance with an ultra finish process at extra cost if necessary. If loops are used, when the optic is hung there may need to be some clocking to equalize the tension to the level required.

We note that if steel is used rather than silica there are two advantages. Firstly the quality factor of the resonances will be reduced by at least two orders of magnitude, therefore easing the notch requirements. Secondly the matching of violin modes should be easier to achieve.

5) Will there be a problem with matching stress in all the wires? Will yaw and roll be able to be controlled well enough?

To date no requirement has been given to the SUS team concerning matching stress in all the wires. See response to 4) above.

Regarding yaw control - we have provision for actuation at both the penultimate mass and modecleaner mirror, which is done using LIGO 1 style OSEMs where the magnets are attached to the masses and the coils to a reaction plate rigidly attached to the isolation platform. (See document by Phil Willems T020059-01-D in which he shows that a reaction chain is not needed from noise considerations). LIGO 1 OSEMs can deliver 20mN/A. The current limits are 500 mA during acquisition and 150 mA continuous. (ref e-mail from Jay Heefner 24 Oct 2005). The current modecleaner model force to displacement transfer function at the mirror is ~2.4 rad/Nm (in both yaw and pitch). There are two coils separated by 96 mm. Putting all these numbers together, we can apply ~ 2mrad peak motion and ~0.7 mrad continuous. We believe this is adequate. Global control will be tested at LASTI. If more torque is required we can use a different design of OSEM, based on those being developed for the heavier quadruple suspensions.

We are not aware of any requirement on roll control, apart from adequate damping of the low frequency roll modes. We have checked this with David Reitze and Peter Fritschel who also do not see any need for roll control apart from damping. We welcome clarification from the review team as to why they believe such control might be necessary, and also if they think that there might be a difference in ability to control using steel rather than silica in the final stage of the suspension.

6) Is beam jitter in the mode cleaner being studied? Will the wire suspension meet the specifications for this? How coupled to initial LIGO experience is planning here?

Firstly, there will be pitch control similar to the yaw control described above which should give adequate authority. We also have noise performance requirements in terms of