Advanced LIGO suspensions summit March 2004-03-21

Session on magnetic moments

1. Robert Scofield reported that there are problems on LIGO with noise from magnetic interference – these may prevent LIGO reaching SRD. He has not formally documented his studies, but he wrote an extended email to Dennis Coyne, who undertook to dig it out and send to Janeen for daylinks. Suggestion is to ensure that the moments in Advanced LIGO are at least no bigger than for LIGO.

2. There are two parts to this:

- the size of the fields that impact the suspensions. We should aim to ensure that the magnetic field environment of advanced LIGO is no noisier than that of LIGO;
- the suspensions' susceptibility to those fields. Here again, we should make sure that the susceptibility is no worse than for LIGO.

3. Within the susceptibility, there are two effects to consider – direct fluctuating forces and fluctuating moments. It is assumed that the magnets are arranged in pairs, or in sets, so orientated that their fields will cancel when measured at a distance large compared to their separation. For the direct forces, the idea is that we will see an effect of fluctuating fields within a volume of space whose size is related to the separation of the two "cancelling" magnets. For the moments, there will be a moment caused by the separation of the magnets and this moment will be proportional to the distance between them. It is assumed that the fluctuation of the forces will also vary with the distance between them, and so the separation appears twice (as a square term) below.

4. In algebraic terms, we need to satisfy, for each stage which has magnets on it:

Forces:

$$\mathrm{M}_{advLIGO} \le \mathrm{M}_{LIGO1}\left(\frac{\tilde{X}_{advLIGO,stage}}{\tilde{X}_{LIGO,testmass}}\right)_{\min overfrequencyrange}\left(\frac{mass_{advLIGO,stage}}{mass_{LIGO,testmass}}\right)\left(\frac{D_{LIGO}}{D_{advLIGO}}\right) \quad (1)$$

where

M = magnetic dipole moment of magnets on a stage. It is thought that M_{LIGO1} is 0.0107 Am^2

$\tilde{X}$ = value of SRD displacement – take the worst case ratio over the frequency range which is likely to be near 10Hz.

D = the distance separating "cancelling" magnets

Moments:

$$\mathrm{M}_{advLIGO} \le \mathrm{M}_{LIGO1}\left(\frac{\tilde{\Phi}_{advLIGO,stage}}{\tilde{\Phi}_{LIGO,testmass}}\right)_{\min overfrequencyrange}\left(\frac{I_{advLIGO,stage}}{I_{LIGO,testmass}}\right)\left(\frac{D_{LIGO}}{D_{advLIGO}}\right)^2\left(\frac{d_{LIGO}}{d_{advLIGO}}\right) \quad (2)$$

Where

$\tilde{\Phi}$ = value of SRD rotation about the relevant axis

I = moment of inertia of mass in the relevant direction

d = beam offset distance

5. Notes:

a) we need to consider the displacement at the stage we are checking and compare it with the displacement at the tst mass in LIGO.
b) In the second expression the *D* term is squared – once for the magnetic effect and again for the size of the moment generated
c) The *d* in the second expression may be taken account of in SRD for the rotation – be careful not to count the ratio twice. On the other hand, that ratio is likely to be 1 or close to 1.
d) It is likely that the moment effect (the second expression above) is the tougher to meet.
e) See G990079-29-M for other relevant info

6. Robert tried a mumetal kit at the ETF at Stanford to see if the magnetic radiation from the SEI table could be reduced – with a little thought it was possible to reduce effects by factor 5 using very thin sheet (4 thou by 8 1/2 by 11 ~ 0.1mm by A4).

7. He noted that there are strong sources of magnetic effects with frequency components in the 55-60Hz range – so it would be prudent to avoid structural resonances in that range.

8. In principle one might consider making actuators with magnets mounted back-to-back. (N-S/S-N). But the coil to drive such a magnet pair would likely generate much larger fringe fields and so it was not clear, even if such an arrangement could generate the required forces, that is would be beneficial.

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