LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

RECORD OF DECISION/AGREEMENT (RODA)

Document	LIGO-M 080134-00 -Y
Date:	11th July 2008
Title:	RODA: E/ITM and BS/FM pitch frequencies and d-values
To the Attention of:	Aligo_sys, aligo_sus, aligo_isc
cc:	
From/ signatories:	Name/Title: Norna Robertson (SUS leader) Signature: Norna A Robertson Name/Title: Peter Fritschel (ISC leader) Signature: Peter Fritschel Name/Title: Justin Greenhalgh (SUS UK/RAL pro Signature: Justin Greenhalgh
System(s) affected:	☐ Initial LIGO ☑ Advanced LIGO ☐ Other:
Nature/ Scope:	☑ Design Decision ☐ Requirements Decision ☐ Work Scope Decision ☐ Working Agreement between Groups ☐ Other
Subsystem(s) affected	☐ Relevant Subsystem(s)/Component(s): SUS, ISC ETM, ITM, BS, FM
Primary Contacts	Group or Affiliation and Contact: Norna Robertson (SUS), Peter Fritschel (ISC)
Reference Documents:	

DECISION/AGREEMENT STATEMENT:

The choice of the d-values (the vertical distances of the attachment points to the masses with respect to the centre-of-mass position at each mass) will be made such that the first pitch modes of the ETM, ITM, BS and FM suspensions lie above the first longitudinal modes for these suspensions. The proposed change is to make the effective d value for the wires attaching to the penultimate mass from above (known as d2 in the MATLAB and Mathematica models) be equal to 10 mm for all of the above suspensions. Here “effective value” is the value which gives the same physical behaviour as would be obtained for an infinitely flexible wire attached a physical distance in the vertical direction of 10 mm above the centre of mass. In practice given the finite stiffness of the wire the attachment point would be closer to the centre of mass.

Background

The default set of d values which have been used in designing the ETM/ITM suspension is to have all of the "effective" values equal to 1 mm in the stable direction at each mass. This value is historic, as chosen for the GEO suspensions. It assures that all the values are in the stable direction set at a value which can be realised in practice, while minimising the resonant frequencies of the pitch modes and hence maximizing the isolation.
The ISC group has pointed out that having a low pitch mode significantly increases the amount of seismic excitation which reaches the mirrors. For example the expected seismic input at 0.32 Hz is 30x higher than it is at 0.47 Hz (ref e-mail from P Fritschel, 1 Oct 2007), where 0.32 Hz was the default choice of first pitch mode frequency for the quadruple pendulum noise prototype and 0.47 Hz was the corresponding value in the controls prototype. In the controls prototype, d values had been set higher to ensure stability when instability problems were being investigated and all the physical parameters which affected stability had not been fully appreciated.
More seismic excitation leads to two potential problems:

i) increased test mass angular fluctuations making locking more challenging, and

ii) more challenging implementation of SPI (matching transfer functions of the SPI mirror and the test masses was found to be harder to do).

The increase in pitch mode can in principal be done by adjusting d values at any of the masses. Changing one d value at the penultimate mass involves the least change to the design of the suspension - only the prism used to define where the wire coming down from above touches the mass needs to be changed. Choosing an effective d value of 10 mm gives a pitch mode of 0.52 Hz (for the quad design at time of writing this RODA), whereas the first longitudinal mode is 0.43 Hz.

It has been checked that with the higher pitch frequency, there is still sufficient pitch DC adjustment range (ref e-mail from P Fritschel, 22 Oct 2007 copied below)

- I use the case where d2 is increased to 10mm; all other d's at 1mm

- Top mass torque to TM pitch ratio, at DC, is 3.6e-2 rad/N-m (this is a factor of 3 smaller than with all d's at 1mm)

- There is only 1 top mass actuator for pitch, with a lever arm of 78 mm

- Max torque, assuming a max DC coil current of 0.15 A, is then:
  2 N/A * 0.15 A * 78e-3 m = 2.34e-2 N-m

- TM pitch range: 2.34e-2 * 3.6e-2 = 0.84 mrad-pk

We're requiring +/- 0.5 mrad of pitch and yaw adjustment, so it's OK. We'd need 90 mA of coil current to get 0.5 mrad.

Beamsplitter/Folding Mirror design

It is prudent to follow the same philosophy for the beamsplitter design as for the ETM/ITM design in respect of the choice of d values. Since the folding mirror suspension is chosen to be identical to the beamsplitter (RODA 040006-00) it follows that any change made to the beamsplitter design also applies to the folding mirror.

Using the same suggested change of d value at the penultimate mass (where in this case the penultimate mass is also the intermediate mass of the triple suspension), gives the frequencies for the first pitch mode to be 0.49 Hz and the first longitudinal mode to be 0.42 (for the current beamsplitter model as in T040027-03-R).