LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

ADVANCED LIGO RECORD OF DECISION/AGREEMENT (RODA)

Document	LIGO- M0900034-v4
Date:	5th April 2010
Title:	RODA: Magnet sizes and types and OSEM types in Adv. LIGO suspensions
To the Attention of:	
cc:	
From/ signatories:	Name/Title: Norna Robertson (SUS leader) Name/Title: Peter Fritschel (ISC leader) Name/Title: Justin Greenhalgh (SUS UK/RAL project manager) *See the LIGO Document Control Center (DCC) for electronic approvals*
System(s) affected:	☐ Initial LIGO ☐ Enhanced 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, SYS, ISC
Primary Contacts	Group or Affiliation and Contact: Norna Robertson (SUS), Peter Fritschel (ISC)
Reference Documents:	T060001, G060003, T080065

DECISION/AGREEMENT STATEMENT:

Advanced LIGO suspensions will use types and sizes of magnets and types of OSEMs as given in Table 1.

Affected suspensions are: ETM and ITM quadruple suspensions, BS and FM triple suspensions, HAM large and small triple suspensions, OMC double suspensions, SOS single suspensions.

TABLE 1	OSEM Type, Magnet Type and Size		
Suspension Type/Stage	**OSEM Type**	**Magnet Type**	**Magnet Size**
			(diam x thickness)
ETM/ITM top	BOSEM	NdFeB	10 mm x 10 mm
ETM/ITM upper intermediate (UIM)	BOSEM	SmCo	10 mm x 10 mm
ETM/ITM penultimate (PUM)	LIGO 1 OSEM	SmCo	2 mm x 6 mm
BS/FM top	BOSEM	NdFeB	10 mm x 10 mm
BS/FM middle	BOSEM	SmCo	10 mm x 5 mm
HSTS (for IMC and RMs) top	BOSEM	NdFeB	10 mm x 5 mm
HSTS (for IMC and RMs) middle	LIGO 1 OSEM	SmCo	LIGO 1 size: 0.075" x 0.125"
HSTS (for IMC and RMs) bottom	LIGO 1 OSEM	SmCo	2.0 mm x 0.5 mm
HLTS top	BOSEM	NdFeB	10 mm x 10 mm
HLTS middle	LIGO 1 OSEM	SmCo	LIGO 1 size: 0.075" x 0.125"
HLTS bottom	LIGO 1 OSEM	SmCo	2.0 mm x 0.5 mm
OMC SUS top	BOSEM	NdFeB	10 mm x 10 mm
SOS	LIGO 1 OSEM	SmCo	LIGO 1 size: 0.075" x 0.125"

For all eddy current damping applications NdFeB magnets will be used.

Background.

1) Choice of material.

Initial LIGO suspensions and prototype Advanced LIGO suspensions have used NdFeB magnets. Rai Weiss and colleagues investigated Barkhausen noise from NdFeB magnets and presented evidence that Barkhausen noise was the leading explanation for observed upconversion noise in Initial LIGO interferometers. They also demonstrated that SmCo magnets exhibit much less Barkhausen noise. The Enhanced LIGO Magnet Swap Review Committee supported the proposal to replace the NdFeB magnets on the ETMs with SmCo magnets for Enhanced LIGO. See the committee report LIGO-M080034-00 for more details. The magnets have since been swapped and there is evidence that the Barkhausen related upconversion has been reduced. See the 16-Dec-2008 LLO elog entry.
The strengths of NdFeB and SmCo magnets have been measured to be within 10% of each other in magnetic moment with equal volume, where the type of SmCo tested was SmCo2:17-27 – see table 1 on page 39 of T0900061-v1.
SmCo magnets can withstand higher temperatures, and do not require Ni plating. The SmCo magnets used in Enhanced LIGO are not plated.
The vacuum review board has approved the use of SmCo as a LIGO Vacuum Compatible Material.

(ref. LIGO-L0900011-v1).

The cost of SmCo magnets is more than NdFeB (currently a factor of ~3 larger), but the overall cost of magnets is not significant compared to other items and so cost is not a strong factor.

Given the experience with Barkhausen noise it is prudent to use SmCo magnets at the most sensitive places in the Advanced LIGO suspensions, namely at all places where dynamic control signals are applied. Thus NdFeB magnets will be used only at the top mass of the multiple stage suspensions. NdFeB magnets are Ni plated to avoid corrosion and this plating makes them more robust for handling. The risk of chipping larger (and hence stronger) magnets is clearly more severe and so using NdFeB for the large magnets at the top stages is a risk reduction step.

2) Sizes of magnets

The sizes of magnets have been chosen from consideration of the necessary actuation forces needed at each stage in the various suspensions. Actuation for the ETM and ITM suspensions is discussed in T060001 and G060003. Actuation for the BS, FM HSTS and HLTS is discussed in T080065

3) Pairing of magnets

As discussed in T060001 and G060003, shielding magnets are needed for the ETM/ITM UIM and PUM stages to reduce the forces due to interaction with external fields. This has already been incorporated into the design of the holders for these magnets, see D070234 (PUM) and D060385 (UIM).

Specific 'off-the-shelf' part suggestion for HSTS bottom magnets:

MMC Enterprises
P/N: SCDS-079-020
SmCo 2-17 28 MGOe
Disc 0.079"Dia x 0.020"Tk

Changes made in version 4 of this document.

A) The size of the magnet for the lowest stage of the HLTS has been updated to be 2 mm x 0.5 mm, the same size as used in the HSTS at its lowest stage. Copy of e-mail from Peter Fritschel (15 March 2010) on this topic in reply to e-mail from Norna Robertson is given below.

Norna,

One could reasonably go either way with the magnet size on the HLTS. In terms of noise (electronic or via B-field
coupling), for the larger magnets, the 6-7x higher mu is somewhat compensated by the 4x higher mass. There's
probably enough margin in the noise to allow for that (though one should go through it in detail, using actual
coil driver noise levels).

On the other hand, the control range with the smaller magnets will be sufficient, and there will be that much more
margin for noise. I'd recommend going with the smaller magnets for the HLTS optics.

Peter

On Mar 14, 2010, at 5:25 PM, Norna Robertson wrote:

> Peter, Matt
>
> I have found a discrepancy between a couple of documents regarding what size of magnet we should use on the bottom mass of the HAM large triple suspension, HLTS, (optics PR3 and SR3.) The RODA on use of magnets M0900034 has the size at both the middle and bottom mass as the LIGO 1 size 0.075 inch diam x 0.125 inch thick (approx 2 mm x 3 mm). This is different from the small triple HSTS (used for PRM, SRM, PR2, SR2 and the input modecleaner optics) where the middle mass has this size but the bottom mass has smaller magnet size, namely 2 mm x 0.5 mm. I do not recall the source of the info which I used for the RODA. However I noticed yesterday when preparing FDR documentation that Jay's electronics doc T080065-E-C which is based on your write up at
> http://ilog.ligo-wa.caltech.edu:7285/advligo/TripleSuspensionActuation
> assumes that "all" the recycling cavity optics have the smaller size of magnet at the bottom mass.
> Is that correct and the RODA wrong? We are about to go through the final design review for the HLTS and our current design, drawings etc have the same magnet size at middle and bottom mass. We would like to get this resolved soon in case we need to change things.
>
> Background info - the optic mass of the small triple is ~ 3 kg and large triple is ~12 kg.
>
> Thanks
> Norna

B) A statement has been added clarifying the type of magnet to be used for eddy current damping (both for overall damping of a suspension and for damping internal modes of blades). Since these magnets are not connected with the application of dynamic (global) control signals there is no need to use SmCo magnets and therefore NdFeB magnets can be used.