LIGO Laboratory / LIGO Scientific Collaboration

LIGO- M060062-00-M *LIGO* 4/26/2006

HAM Single-Stage Isolation Baseline Option Review Report

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LIGO Science Collaboration

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Introduction

A review was held on April 14, 2006 to determine whether a single-stage active HAM SEI could be substituted for the double-stage system, which is currently the baseline for AdLIGO. Revised performance requirements for the HAM SEI were proposed by Peter Fritschel and reviewed on April 11. A summary of these requirements is given below. Brian Lantz gave a presentation (G060190) to the review committee (members listed below) describing the analysis of a single stage HAM SEI with specific control laws and these were compared to the proposed revised HAM requirements.

Findings

The findings of this review committee are:

- The single stage HAM with the control laws, as illustrated in G060190, provides good performance at frequencies above 1/2 Hz consistent with the revised requirements
- Most of the performance claims have been demonstrated with the Technology Demonstrator.
- The single stage system with the control laws illustrated in G060190 meet the revised requirements for the amplitude spectral density at 10 Hz and for the rms motion at 0.6 Hz.
- Performance below 0.6 Hz (both in amplitude spectral density and rms) fell short of requirements in the modeling to date and further work is needed to derive control laws that will meet these requirements. However, it is noted that a double stage does not help meet those requirements, since most of the low-frequency performance is determined by the first stage.
- HAM HEPI motion, particularly rotation about the y-axis, limits the predicted performance at frequencies below 0.4 Hz. Here, the observed rotational performance of the HAM-HEPIs is poorer than the BSC-HEPIs, which may be due in part to sensor confusion between tilt and local twisting. There is good reason to believe that the rotational performance of the HAM HEPIs can be improved, which would bring the predicted single-stage ISI performance closer to the target level. Better filtering strategies may also be helpful in improving low-frequency performance.
- Overall, the single stage is easier to build, commission, and maintain than is the double stage system that is the current baseline for AdLIGO. At this point in time it appears as capable of meeting the revised requirements as the double stage system. It appears from what we know that it would be reasonable to change the AdLIGO baseline for HAM SEI to a single stage of active isolation, supported by a HEPI system as discussed in G060190 and to schedule investigations of the improvements to low-frequency performance that might be possible from a better understanding of tilt couplings introduced in the HEPI plant and from better filtering in the controls. This concept could be the basis for a preliminary design when appropriate.

The committee also notes:

- The analysis of the single stage HAM SEI that was reviewed made no assumptions about rejection or control of common-mode motion. Rather it was assumed that each HAM platform needed to reach its required level of motion independently of other tables. A better understanding of common mode motion or strategies to link adjacent tables by sensors and controls might lead to projected improvements at low frequencies.
- The review of the revised HAM requirements noted a number of issues that needed further investigation (see below). As these issues are studied, there is the possibility that these will place further constraints on the HAM SEI design.
- A conceptual design document is needed that documents the single stage HAM design and control laws.
- The material reviewed assumed that HEPI would be used with the single stage HAM design. Further simplification and cost savings might be achievable if there were applications for the single stage system without HEPI. Management may want to consider further the performance of a single stage without HEPI and its possible applications in a future review.
- A new design for the "gullwing" support structure for the HAMs, that may alleviate some problems that affect performance of the HAM/HEPI system, is part of the baseline plan. The possibility of integrating the new support structure into LASTI testing should be considered.

Summary of Proposed Revised Requirements

Horizontal:
$< 4 \times 10^{-11}$ m/√Hz at 10 Hz in the horizontal directions.
1/f shape below 10 Hz, emphasizing low noise at the suspension resonance at about 0.65 Hz.
Performance in the microseism similar to the BSC requirements.

Angles:
Yaw, rms $< 1 \times 10^{-8}$ rad above 0.2 Hz, factor of 10 higher when lower frequencies are included.
Pitch, rms $< 1 \times 10^{-8}$ rad.

Considerations not yet studied in setting revised requirements

- Relative HAM platform motion at low frequencies: the seismic isolation system could make the relative motion between two HAM platforms larger than it is when just driven by ground motion at low frequencies (<0.5 Hz); how much relative motion (for the different DOFs) do we allow?
- Effect of HAM platform motion on the output mode cleaner
- Effect of HAM platform motion on (non-suspended) beam reducing telescopes, and implications for signal detection

- Analysis for single- or double-suspensions, as might be used within a stable recycling cavity configuration
- How much position control is needed for the HAM platforms?

Review committee members

Rana Ahikari
Dennis Coyne
Peter Fritschel
Joe Giaime
David Ottaway
Fred Raab (chair)
Norna Robertson

Charge to the Committee

(Reprinted from LIGO-CAW001-06 for completeness)

The Advanced LIGO management wishes to carry out a review of a proposed single stage approach for the HAM in-chamber seismic isolation for AdL. The immediate question is whether the single stage design, as understood to date, will meet the revised HAM requirements.

The baseline Advanced LIGO design includes a stiff, two-stage, HAM isolation system based on a design from ASI. The high cost and complexity of this design leads to a desire to reduce costs and to simply the design and operational complexity. This desire, coupled with the recent re-evaluation and relaxing of the HAM seismic isolation requirements, has lead the Advanced LIGO management to consider viable alternatives to the baseline design.

The seismic isolation team has presented a plan for a single stage, stiff design based on the ETF technology demonstrator at Stanford. The design at this time has not yet met the definition of a preliminary design. See definitions below from Guidelines for Detector Construction. Therefore this review should be considered at the level of a conceptual design review.

Given the above considerations, the charge to the committee is as follows:

1. Evaluate the presented conceptual design to determine if it is consistent with the recently updated design requirements document,

2. Advise on whether the design, if Advanced LIGO management chooses to pursue further development, is sufficiently developed to proceed with a preliminary design phase, and

3. List any missing elements that are necessary for the presented design to satisfy items 1. and 2.

We would like the review to take place by 14 April, 2006., with a report to me to follow as soon as possible, but no later than April 28, 2006.

Excerpts from Guideline for Construction, LIGO M050220-00-D

- *Conceptual design* — Generate a conceptual design of the subsystem in sufficient detail to show that the subsystem is completely characterized by the entries in the Design Requirements Document and is understood well enough to proceed with preliminary design.
- *Preliminary Design Phase* --- Develop the subsystem to the point where *all design issues are resolved,* lacking only the detailed engineering drawings, specifications and contract documents needed for implementation.