LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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OMC Suspension Advanced LIGO Test Plan

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1 Introduction

The purpose of this document is to lay out the series of tests which should be performed to verify that each OMC suspension is operating as designed. It builds on and supercedes two previous documents: E070068-01, the Output Mode Cleaner Suspension Test Plan, and T080105-00-R, Output Modecleaner Suspension ELIGO test plan. It is divided into two sections. The first details the tests to be made after first assembly with a dummy metal bench. The second details the tests to be made after installation with the silica optical bench. This plan covers the mechanical aspects including basic BOSEM functionality. There is a separate controls test plan covering the electronics (currently available at http://www.ligo.caltech.edu/~jay/documents/T080008-00-C.pdf).

2 Tests after first assembly.

2.1 Mechanical fit test

The mechanical fit test will use the dummy optical bench and will validate that all mechanisms work, all parts fit together and no fabrication errors or drawing errors exist.

2.2 Configuration Documentation.

A record of all parts with their masses will be kept during assembly. Moment of inertia and/or center of gravity for all key parts will be measured or calculated. Added mass or adjustment mechanisms will be recorded. Pictures will be taken to document the suspension.

2.3 OSEM tests.

Review OSEM test data provided, to confirm all OSEMs have been functionally tested prior to installation. Check that all OSEMS are functioning and centred after installation. Dynamic range of all OSEMs after installation should also be checked.

2.4 Pendulum frequency and transfer function tests

Swept sine excitation of suitable combination of OSEMs for each degree of freedom will be used to generate transfer functions in 6 degrees of freedom at the top mass (from coil drive to OSEM sensor output), without active damping. Comparison will be made with transfer functions and frequencies predicted using the Matlab/Simulink design model of the suspension. The frequency range will be as large as practicable within the limitations of sensor noise and acoustic noise in the lab. Mode frequencies should be noted and should agree with the model within a few percent. Frequencies can be identified from the transfer functions. Alternatively the frequencies of the suspension can be measured as follows. A step input of order 10 mN in x, y, z and 0.5 mN·m in yaw, 0.1 mN·m in pitch and 1 mN·m in roll should be applied via the OSEMs at the top mass with the local servo off, to excite as many low frequency modes as possible. All of these numerical values are rough recommendations based on what was found was good for a triple pendulum suspension. They excite the pendulum to give displacements at the OSEMs that are a significant fraction of the linear range of the shadow sensors. The output of the top mass OSEMs will be logged for approximately 5 minutes and FFTed to produce frequency spectra.

2.5 Damping tests

Check that the 6 degrees of freedom can be adequately damped (damping times of 10 seconds or less to amplitude of 1/e). Check that the damping works over the required range of alignment from the mean position as specified in the requirements document T070189-v1.

The OSEMs can be used to measure the damping response of the pendulum under local control as follows. A step input of order 10 mN in x, y, z, 0.5 mN.m in yaw, 0.1 mN.m in pitch and 1 mN.m in roll will be applied via the OSEMs at the top mass with the local servo <u>on</u>, to excite as many low frequency modes as possible. The output of the top mass OSEMs will be logged for approximately 1 minute and plotted to check that all modes are dying away as expected according to the Matlab/Simulink model of the pendulum and local control system, and in compliance with the requirement. For the test with damping on, if there are any modes still ringing significantly after 1 minute there is something wrong in the design of the controller or dampers and debugging needs to commence. Repeat with the damping off to observe the natural damping time. Note that this is affected by whether there is electronic cabling in place between the bench and the structure. With cabling the decays (to 1/e) observed are typically several tens of seconds.

As before, these step inputs are rough recommendations for a triple pendulum suspension, although they should be about right for the double as well.

2.6 Dynamic range

Check that the required range of alignment (few 100 microrad TBC) can be achieved.

2.7 Alignment test

Check that the dummy bench is adequately aligned and hanging at the correct height. The bench should be hanging at a height such that the beam is 101.6 mm +/- 2 mm [4.0 inches] above the HAM optics table. Since the beam runs 20 mm below the lower surface of the baseplate, this implies that the lower surface of the baseplate should be 121.6 +/- 2 mm from the optics table. Regarding the angular alignment, this should be within the range of the tip-tilt mirrors. A difference of 0.5 mm over the length of the baseplate of length 450 mm (which is approx 1 mrad) is acceptable and measurable with a ruler. Check also that the top mass is hanging at a height such that the OSEMs are able to be aligned. Alignment should be accomplished by adding and removing masses from the top mass, and/or the bottom mass as appropriate.

2.8 Interface to ISC

The mass and moments of inertia of the actual optical bench will be provided to SUS by the ISC group. Comparison will be made between the dummy bench as tested in the suspension and the actual optical bench as its design matures. If required, additional tests will be carried out with an altered dummy bench matching the actual optical bench's parameters, to check that the resulting behavior still meets requirements.

3 Tests after installation.

3.1 Repeat steps 2.3 to 2.7 above

Two further tests which could carried out in conjunction with other systems are as follows.

3.2 Structure resonant frequencies and interactions with HAM-ISI

It is of interest to see what is the frequency of the lowest structure resonance when attached to the HAM-ISI table (frequency measured to be ~ 140 Hz when attached to a rigid heavy table) and to see if it has any effect on the ISI performance. In ELIGO tests the resonance was seen at ~ 103 to 110 Hz when the structure was not tied down as firmly as recommended by the SUS group. We expect the frequency to be significantly higher with the use of the recommended number of dog clamps (as per installation procedure E070271-05-D). Clamps should be checked and tightened if necessary.

This investigation requires input from the SEI group.

3.3 Isolation performance as seen from OMC signals

There is no set-up to make a direct measurement of the isolation performance of the double pendulum. Its performance can to some extent be inferred from the TFs taken in 2.4 above. However it may also be possible to use an OMC signal to infer an upper limit to the performance, e.g. by observing the level of jitter. This investigation requires input from the ISC group