OUTPUT MODE CLEANER SUSPENSION TEST PLAN

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Overview

The following test plan details the tests required to qualify the output mode cleaner suspension for Enhanced LIGO. The tests are designed to reduce risk as the designs move forward into Advanced LIGO. They are also designed to provide results that will be used to determine if the designs meet the suspension requirements. Further tests on the OMC will be carried out by the ISC team (reference ISC test plan document TBD).

Key Tests

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. Mechanical parts will be wiped down with alcohol prior to assembly, at a minimum. Ultrasonic cleaning is preferable, if time allows.

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.

3. **Structure frequency measurements**

A piezo, impact hammer or another mechanical means will be used to induce vibration in the clamped-down structure. The mass to which the structure is clamped shall be much more massive than the suspension assembly and mechanically as stiff and non-lossy as possible. A large milling machine bed is ideal – an optical table is not suitable. An optical table may give frequencies that are lower than the final configuration. All non-suspended parts shall be assembled onto the structure, or comparable mass bolted in place. The suspended items should be included, if feasible. About as many clamps should be used as will be used in production. Low mass accelerometers with strain relieved cables will be used to identify at least the lowest-order longitudinal and transverse leaning modes and the lowest-order torsional mode of the structure, as well as any other low frequency modes that violate the minimum frequency requirement. A low frequency mode might be a bending mode of a single structural member. These modes need to be identified to determine if damping or re-design is required. Comparisons will be made with the finite-element model of the structure produced by the CAD software. Measurement procedure detailed in T050237-03

4. **Functional electronics and OSEM test.**

This test is a stand-alone test of the analog electronics, digital electronics and the pcix-based electronics system along with all cabling. A single spare OSEM suffices for this test. Review

OSEM test data provided, to confirm all OSEMs have been functionally tested prior to installation. Dynamic range of all OSEMs after installation should also be checked.

5. **Pendulum frequency and transfer function measurements**
The OSEMs will be used to measure the pendulum frequencies of the suspension. 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 will 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. 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), both with and without 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.

6. Damping test
The OSEMs will be used to measure the damping response of the pendulum under local control. 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 on, 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 10 s (or TBD) or less requirement.

As before, these step inputs are rough recommendations for a triple pendulum suspension, although they will probably be about right for the double as well. For the test with damping off, we're trying to get good resolution of the mode frequencies, so we want to sample for many periods. 300 s should give roughly 1% accuracy for modes around 0.3 Hz. 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.

7. Alignment test
Mechanical alignment will be checked for the suspension. Suspension alignment requirements are detailed on the Advanced LIGO wiki, http://ilog.ligo-wa.caltech.edu:7285/advligo/OMC_Suspension_Specs.
Gross alignment should be accomplished by adding and removing masses from the top mass. Details of this procedure may be found for the input mode cleaner in T030147-01 A small mirror will be mounted to the dummy bench, D070027, and a HeNe laser will be used to check the pitch, roll and yaw of the bench. The height of the bench will be measured. Fine alignment of the dummy bench will be provided by the OSEMs and will be tested using the optical lever. Optical levers may also be used for residual motion measurements.

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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. Threaded holes are provided by the SUS group on the top mass for cable strain relief from the optical bench. Interface of optics mounted separately to the suspension components should be checked. These are the ISC input/output optics that will be mounted on the optics table, inside of the suspension structure, or mounted to the structure itself.