LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Suspension Test Plan

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detector

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1 SUSPENSION TEST CRITERIA

Several parts of the preliminary suspension design will be built and tested to evaluate its feasibility and performance in preparation for the final design. Any difficulties encountered during assembly and testing will be corrected and fed into the final design.

1.1. Fixtures for Gluing Attachments

Fixtures designed to hold the optics while gluing the attachments at precise locations will be tested. The attachments consist of the magnet assemblies and the guide rods. Aluminum models will be made of the Test Mass (TM) and the Mode Cleaner Mirror (MCM). The models will include a typical wedge angle. The following tasks and tests will be done.

- The fixtures will be built.
- The model optics will be installed with their wedge angles appropriately oriented.
- Attachments will be glued to the model optics.
- The ease of assembly, alignment and gluing will be checked.

1.2. Construction and Alignment/Fit Checks

There are three configurations of the large and small suspension assemblies that will be checked. See Table 1 below. The LOS1 structure will be tested in two configurations. Configuration 1 includes a height adapter that is attached to the top of the suspension structure which permits bolting to the optics platform in the BSC. See Figure 1.

Table 1: Possible configurations of the large and small suspension assemblies and their associated vacuum chamber

Configuration	*Suspension Type*	*Suspended optic and tentative size*	*Vacuum chamber*
1	LOS 1	TM 25cm x 10cm	BSC
2	LOS 1	RM 25cm x 10cm	HAM
3	SOS	MCM 7.6cm x 2.5cm	HAM

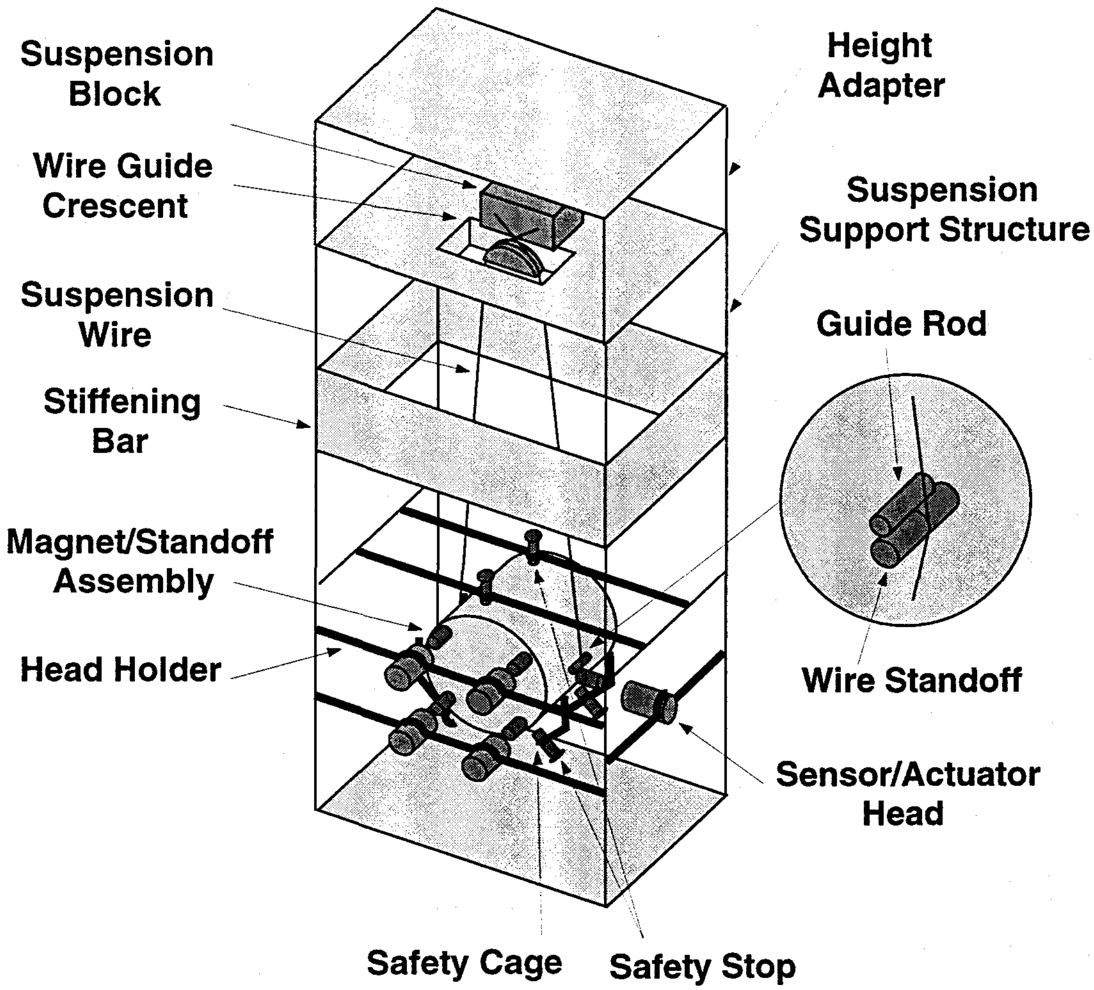

Figure 1: Suspension assembly components.

Both LOS1 and SOS structures will be constructed. Aluminum model optics will be installed and fit checks will be made. A fine alignment procedure will be demonstrated using configurations 1 and 3 of Table 1. A list of tasks and tests is given below.

- Construct each suspension structure.
- Level optical table for alignment tests[1].
- Suspend each model optic and perform a coarse alignment by tapping on the wire standoffs.
- Verify that the magnet assemblies align properly with the sensor/actuator heads.
- Perform a fine optical alignment on the TM and MCM aluminum models as described below. Use a PZT buzzer to adjust the position of the wire standoffs[2] and measure alignment using the alignment fixture. Alignment will be adjusted to absolute level within the required balanc-

1. The Vacuum Assembly Room in the 40-Meter Lab South Annex building is suitable for alignment tests.

ing tolerance.

- Following the optical alignment, the standoffs will be glued in place.
- It will be demonstrated that the optical components can be dismounted and remounted into proper optical alignment, within design tolerances.
- The pitch frequency will be measured to verify that the correct value for d_{pitch} was obtained after gluing. See Figure 2. The frequency shall be 0.60 +/- 0.05 Hz. The measurement will be done in air using the sensor in the sensor/actuator head for readout.
- Verify that f_{yaw} equals 0.50 +/- 0.05 Hz and $f_{pendulum}$ equals 0.743 +/- 0.002 Hz.

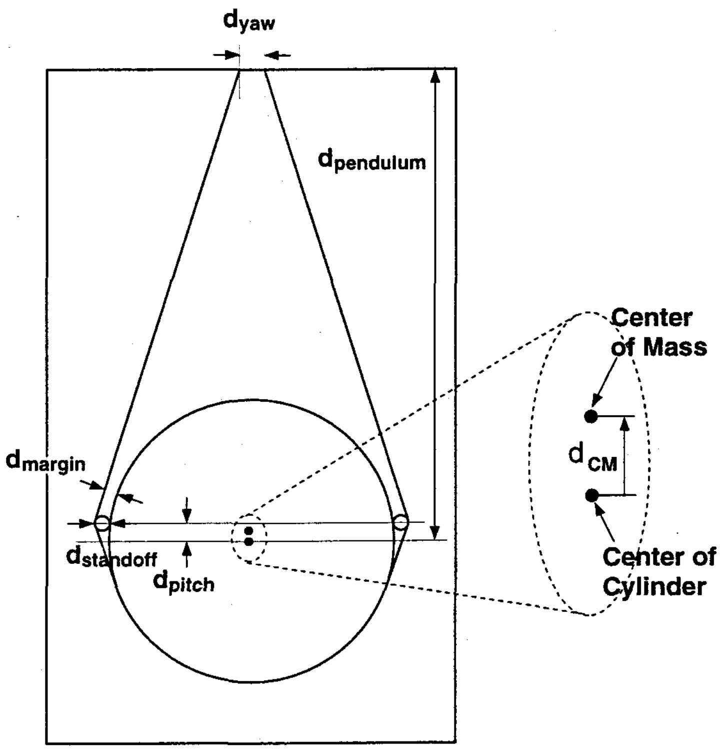

Figure 2: Suspension Configuration

1.3. Installation Tests

The ability to transport a finely aligned optic/suspension structure to an optical platform will be tested. Aluminum model optics in configuration 1 and 3 of Table 1 will be tested. The following steps will be carried out.

2. The PZT buzzer is a rod or tube to which a PZT is attached. The PZT is driven while the vibrating rod is placed against the end of the standoff to produce small displacements of the standoff.

- Following the fine alignment of the model optic, the optic will be locked in its safety cage.
- A removable lifting fixture will be attached to the suspension structure and the structure will be transported away from the optical table and then returned to its original position.
- The optic will then be unlocked and checked for optical alignment to within the required tolerances.

1.4. Frequency and Q Measurements

The suspension development facility will be used to measure the frequencies and Q's of a suspended TM and a suspended MCM. It is assumed that COC will have tested and delivered mirror substrates with the required Q values.

- Substrate vibrational-mode Q's for lowest five axisymmetric modes shall be measured after gluing on all attachments and compared to requirements.
- The violin-mode will be excited using a PZT actuator[1] and frequencies and Q's will be measured with the substrate hanging in its appropriate suspension support structure. The, violin-mode Q's for the lowest three harmonics of both suspension wires shall be measured and compared to requirements.

1.5. Mode Measurements of the Suspension Structure

Measurements of the mechanical resonances of the suspension structures will be made to compare with the FEA modeling. The structures will be bolted to a large proof mass to mimic the situation in LIGO since some modes may couple vibrational energy through the suspension support structure to the proof mass. These modes form a two body system and the system's reduced mass should resemble the situation in LIGO. Otherwise these modal frequencies will shift when placed on a LIGO optical platform. The following task/tests will be done.

- Configurations 2 and 3 will be bolted to the top of an optical table. Configuration 1 will be bolted upside down to an optical table.
- Structural resonances will be excited by tapping on the structure at various spots. The mode frequencies and Q's will be read out using an accelerometer.
- Verify that there are no modes below the gravest mode specified in the design requirements.

1.6. Sensor/Actuator Head Tests

Each sensor/actuator head will undergo the following tests.

- The resistance and inductance of the coil in each actuator will be measured. All coils should measure within +/- 5% of the nominal value.
- The sensor will be tested for operation and alignment of the LED/photodiode pair. A test fix-

1. Attached to the prototype and used to excite through shear coupling.

ture will be placed against a sensor/actuator head. The fixture will protrude far enough into the head to block half of the LED/photodiode pair. The photodiode output voltage will be measured. It shall be 50% +/- 10% of the maximum output voltage prior to insertion of the test fixture. See Figure 3 below.

One actuator coil will be tested in vacuum[1] to establish its current handling capacity.

- A temperature sensor will be glued to the coil and the temperature as a function of current will be measured up to the maximum recommended operating temperature of the insulated wire. The test will be conducted at ten separate operating points. At each operating point, the head will be allowed to achieve thermal equilibrium. The current will then be shut off and the coil and resistance will be remeasured after equilibration has been achieved.

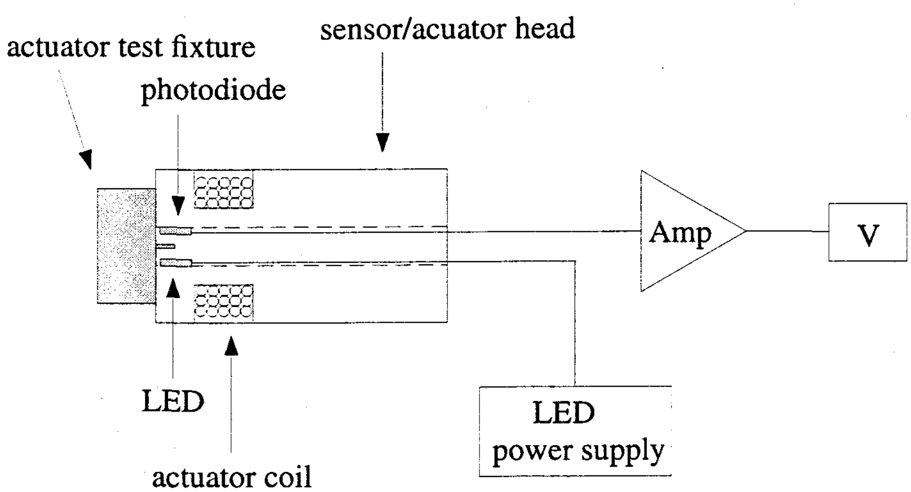

Figure 3: Sensor/actuator head test setup

1.7. Demonstration of Local Damping

It will be shown that critical damping can be achieved under local control making use of the servo electronics which will be made for the beam splitter for the Mark II interferometer. This will be done for a LOS1 suspension and SOS suspension. Aluminum models will be used in place of optical components. The model optic will be given an electrical kick and the displacement as a function of time will be measured using the output of the sensor in the sensor/actuator head.

1. This test may contaminate the vacuum vessel in which the test is performed and may destroy the actuator head.

1.8. Transfer Function Tests

The transfer function will be measured for a LOS 1 suspension and a SOS suspension. Aluminum models will be used in place of optical components. The response of the system will be measured at DC and with AC inputs over the relevant range of frequencies to show that the specified forces and torques can be applied to suspended components. This will demonstrate that there are no mechanical/electrical interactions that affect the stability of the feedback loop. Test signals will be applied to the actuator heads to produce the displacement and torque signals.

1.9. Feedback from R&D

The new test-mass suspension system for the Mark II interferometer will be designed to satisfy (wherever possible) the noise requirements for the LIGO LOS. The new beam-splitter and recycling-mirror suspensions for Mark II are the prototypes for the SOS. The results of noise tests for these systems in the 40-meter interferometer will be fed back to the SUS design for the detector.

1.10. Components and Instruments for Testing

Some of the tests mentioned above require special components or already existing instruments, which are summarized in Table 2.

Table 2: Components to be made and existing instruments for prototype testing

Test	*Components to be acquired*	*Existing Instrument*
Fixtures for Gluing Attachments	Aluminum model optics (TM, BS, MCM). Sizes are **TBD**. Gluing fixtures	N/A
Construction and Alignment/ Fit Checks	Optical alignment components - Hg level. Suspension assembles. PZT Buzzer.	He-Ne Laser
Installation Tests	lifting mechanism	Optical tables in S. Annex Building
Frequency and Q Measurements	PZT actuator	Suspension Development Facility, accelerometer, HP 3962
Mode Measurements of the Suspension Structure	N/A	Accelerometer, HP 3962, optical tables in S. Annex Building
Sensor/Actuator Head Tests	Sensor test fixture	N/A

Table 2: Components to be made and existing instruments for prototype testing

Test	*Components to be acquired*	*Existing Instrument*
Demonstration of Local Damping	Servo Electronics for Mark II (minor modification necessary)	N/A
Transfer Function Tests	N/A	HP 3962
Feedback from R&D	N/A	Mark II