LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO- T040151-02 *ADVANCED LIGO* July 28, 2004

Advanced LIGO Quad Installation &Alignment Fixtures Product Design Specification

Janeen H. Romie

Distribution of this document:
LIGO Science Collaboration

This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW17-161
175 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

http://www.ligo.caltech.edu/

I. INTRODUCTION

This document defines the requirements for the Advanced LIGO installation and alignment fixtures needed for the ETM, ITM, BS and FM suspensions to be installed in the BSC chambers at the sites and at LASTI.

In Initial LIGO, assembly fixtures were defined as the tools required to assemble a suspension, whereas installation fixtures were used to install an assembled suspension into a chamber. So, assembly tools were used to align the optic to the structure to a set of requirements defined by the suspension subsystem whereas the installation tools, in conjunction with alignment equipment, were used to determine the position of the optic with respect to the other optics, and move the structure around on the chamber optical table to meet the final alignment requirements defined by the ASC subsystem. For example, for an end test mass, the alignment requirements for the suspension assembly (optic to the structure) were defined in the Large Optic Suspension Balancing Specification, E970154 and the alignment requirements for the end test mass final installation (optic to optic) were defined in the ASC Initial Alignment Procedures, T970151.

Advanced LIGO is a bit more complicated. However, broad definitions are still the same. Again, assembly fixtures are tools used to assemble the suspension itself. These tools include wire jigs, upper mass assembly rigs and the suspension gazebo that allow for suspension of the blades and mass components and a basic alignment of the test mass to the structure. Installation fixtures will be needed to move each section of the suspension structure, to move both sections together and to transport the sections. Installation fixtures will be needed to move the structure sections relative to the optical table, and relative to each other. Some extra alignment equipment may be required above and beyond the traditional transit square, theodolite, prism and autocollimator.

II. OVERVIEW

The current concept for the Advanced LIGO controls prototype quadruple pendulum suspension has the structure composed of two sections – and upper structure and a lower "catcher" assembly. The product design specifications for each of these are as follows:

T040141, ETM Upper Structure Product Design Specification

T040080, Advanced LIGO ETM (Quad) Controls Prototype Catcher Jig Design Specification

The sections of the structure will be very heavy. Details of the current mass estimates may be found in T030137, ETM Controls Prototype: - Mass Estimate of an ETM Suspension Layout. Currently, with a 22, 22, 40, 40kg, top to bottom mass configuration, and with a full reaction chain, mass estimates are as follows:

Upper structure with non-suspended mass+suspended components=114kg+88kg=**202kg=444 lbs**.

Catcher structure with non-suspended mass+suspended masses = 29kg+160kg= **189kg = 416 lbs**.

Please refer to the latest revision of the mass document for up-to-date numbers.

Photo 1: Concept Upper Structure
In Suspensions Gazebo

Photo 2: Concept Upper Structure & Catcher
in Suspensions Gazebo

III. INSTALLATION SCENARIOS

Because LASTI does not have ceiling clearance, the sections of the quad must be installed in the BSC chamber separately. See Larry Jones's document on SEI LASTI Installation, D030715. The seismic system may be assembled and lifted onto the seismic fixture ("seismic gazebo"), the upper part of the structure may be positioned and mounted to the optical table, and that whole assembly may then be installed into the BSC chamber. After that, the chamber door may be opened and the catcher with its optics may be moved in through the door and positioned and secured to the upper part of the structure, inside of the chamber.

At the sites, a cartridge installation may be utilized where the seismic isolation system may be assembled, lifted into the air onto the seismic gazebo, the upper part of the structure and its assemblies may be positioned and clamped to the optical table and then the lower catcher may be positioned and secured to the upper part of the structure. Then, the whole cartridge may be installed into the chamber.

Currently, the suspensions group has a suspensions fixture, called the suspension gazebo (not to be confused with the more massive seismic gazebo) that will allow for assembly of the upper and lower parts of the structure, and their suspended components, onto a faux optical table mounted at about 8 feet above the floor or 11 feet above the floor (the same height as the Advanced LIGO BSC optical table above the LVEA floor.)

The suspensions gazebo will allow for an initial alignment of the test mass relative to the structure to the pitch alignment requirement of +/- 0.5 mrad and a vertical alignment requirement of +/- 0.5mm. These are working alignment requirements upon which the suspensions group has agreed. It is also assumed that the final configuration of the suspension will meet these requirements before installation. It is assumed that the earthquake stops or some other mechanism will be used to lock the optic and masses in their balanced positions, after full assembly.

The installation and alignment fixtures will be needed to install the suspension onto the optical table and into the chamber and also to remove sections of the suspension in the event of problems. Repair scenarios are detailed in E040329, Advanced LIGO Quadruple Pendulum Suspension Failure Modes and Subsequent Repair Approaches. At least in part, it details the sections of the suspension that need to be accessed and/or removed for repair.

IV. INSTALLATION FIXTURE REQUIREMENTS

1) Upper Fixture

- The upper fixture will be used to position and adjust the upper structure in X, Y, and Z along with Yaw, relative to the global coordinate system identified on the interface layout drawing (ILD), D970310. It will provide for gross positioning, fine alignment and clamping of the upper part of the suspension structure to a faux optical table in a suspension gazebo or a BSC optical table in a seismic gazebo. It is assumed that this fixture does not need to go inside of the chamber.

- The upper fixture should be placed under or around the upper structure and provide course adjustments for linear translations and ultra fine adjustments for angular adjustments.

2) Lower Fixture

- The catcher must be able to move up into the upper structure to facilitate the wire clamps attachment to the blades. This is called the Russian-doll movement of the bottom of the quad structure up into the upper part of the quad structure. The lower fixture must facilitate this movement. The fixture may have to allow for tilt to mate the catcher to the upper structure.
- The lower fixture will provide for gross positioning, fine alignment and securing of the catcher/lower section of the suspension structure to the upper part of the structure. Fixtures will be needed for use outside of the chamber with either of the gazebos. Fixtures will also be needed for use inside of the chamber.

3) Overall Fixture

- An overall fixture will be needed inside of the chamber and outside of the chamber to move both sections of the structure, with their suspended component locked down. It will provide gross positioning, fine alignment and clamping of the whole structure to/from a faux optical table in a suspension gazebo or a BSC optical table in a seismic gazebo. It is assumed that the fixture will need to go in the BSC chamber.

4) Transport

- A fixture or a group of fixtures will be needed to move the structural components from one end of an optics lab to another, from the optics lab to the LVEA, from the LVEA into a portable clean room and from the portable clean room to the area next to the chamber.

V. FINAL OPTIC ALIGNMENT REQUIREMENT

1. The suspension itself has a number of alignment features and mechanisms that may aid in reaching the final alignment requirements. Please reference the quad assembly document for instructions on the use of these features.
2. It is assumed that the optic in the suspension shall be aligned to +/- 0.1 mrad in pitch and yaw. Its position along the laser beam shall be aligned to +/- 3mm. Its side/transverse position must be aligned to +/- 1 – 5 mm. Its vertical position must be aligned to +/-1mm. These alignment requirements are based on the initial LIGO requirements. This may change when the ASC group provides direction.

VI. GENERAL FIXTURE REQUIREMENTS

1. Fixtures must be able to move the parts out of the chamber along with into the chamber, for repair and replacement of parts.
2. Movement of the upper structure relative to the optical table shall not produce debris.
3. After alignment has been achieved, the suspension assembly is to be clamped to the optical table and the upper fixture must be removed.
4. Include in the lower fixture design a prism with part no. 7261-35AP01, manufactured by Sokkia. The prism is to be mounted at a fixed distance in front of the center of the optic. The prism and its support must have the ability to be removable (for a clear view of the optic) and reattached with a repeatability of .005" of the initial position. The prism shall fit on either side of the fixture. These prisms will be used to provide targets for axial and transverse EDM position measurement.

5. Lifting and lower fixtures to allow for smooth movement, in all directions.
6. All fixtures to clear seismic and chamber parts while in use.
7. Lift and transport tables to include provisions which shall prevent the fixture and structure from rolling off of the table.
8. After aligning the suspension and bolting it to the optical table, removal of all of the fixtures must be accomplished without disturbing the suspension assembly or other components on the optical table.
9. Of course, materials used to fabricate the fixtures must comply with LIGO Vacuum Compatible Materials List, E960050. Deviation from this list must be approved by the LIGO Vacuum Board. No painted components may enter the vacuum chamber.
10. All fixtures shall be marked with part numbers.

VII. INITIAL LIGO FIXTURES

A number of fixtures were designed for use with the initial LIGO single pendulum suspensions. Can any/all of the initial LIGO installation fixtures be used, modified and/or reworked to be used with the advanced LIGO components[1] Details on the use of the initial LIGO installation/alignment fixtures may be found in E000062, LOS Installation Procedures for BSC. Also, as reference, E000061, LOS Installation Procedures for HAM Chambers.

As a reference, the initial LIGO LOS suspension weighted ~81 kg = 180 lbs.

1) The initial LIGO fixtures will need to be researched and tested for use with much heavier objects. The alignment fixtures are used in combination with each other and alone. The alignment fixtures we are interested in are the:

   - Transport cart
   - Straddle
   - D980003, Lift Truck/Roller truck
   - D980182, Support Beam (called the Lazy Susan)
   - Shuttle Table
   - D980002, Lift Table
   - D980001, Part of Alignment Fixture, called the Tilt Table
   - Earthquake stops, please reference E021000-05, Earthquake and Safety Stop Design Requirements. The initial LIGO earthquake stops were used for a number of purposes: facilitate suspending and balancing, clamping and protecting. The small screws we used in initial LIGO were adequate for these functions because the masses were relatively small (12kg). However, I believe that if we use screws for the EQ stops for advanced

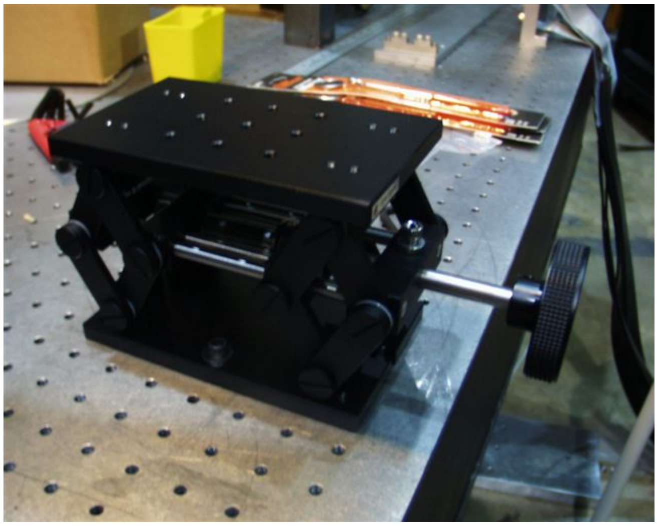
[1] T040107-00-D Brief Summary of Visit to LIGO (Caltech), May 7th – May 15th 2004

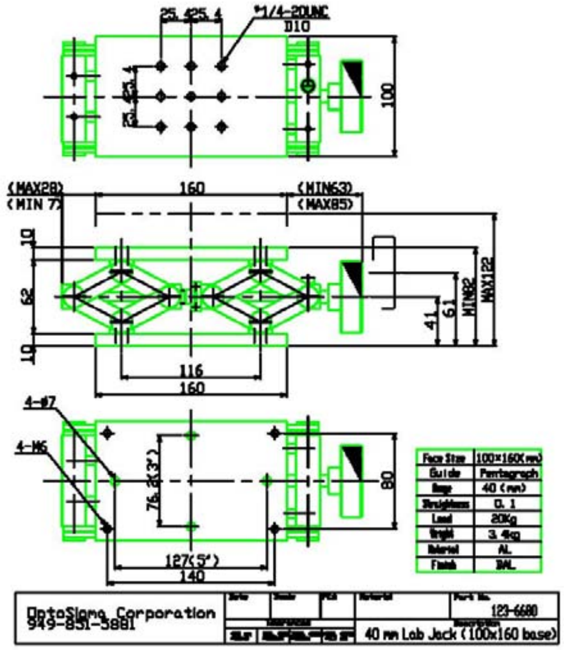
LIGO suspensions – especially glass tipped screws to for electrostatic reasons – I believe that they will only be able to function as protection in the event of an earthquake. The optics will have to be clamped and suspended with other, more robust means.

2) Auxiliary fixtures used in Initial LIGO and in Advanced LIGO R&D that may be used pending research and testing are:

- Teflon Highway – Can we use a piece of Teflon on an optical breadboard with the top section and the bottom section of the quad, separately, and use brass pushers to move the sections in translation and rotation? What kind of resolution can we expect with that kind of weight?
- Counter weights – How will the BSC optical table stay stable while the quad sections are mounted and aligned? Can the optical table be locked down while we mount the sections and then unlocked and then leveled with counterweights or must we counter weigh real-time?
- Lift carts – In the Synchrotron, we've been using 2 carts. One (the orange one, seen in Photo 2) is a hydraulic cart with a lift table. It moves from ~10" off the ground to ~33" above the ground. Can it be Class B-able? The other is a lift table (seen in Photo 1) that has much more range. It is currently very dirty but like the orange cart seems to have good (not fine) resolution. Can this one be Class B-able? Are these appropriate choices for the long term, perhaps in combination with the initial LIGO installation fixtures?

- Vertical Translation Table. Helena has found a sturdy, vertical translation table made by OptoSigma, p/n **123-6680.** It's spec sheet is here: http://www.optosigma.com/miva/merchant.mv?Screen=PROD&Store_Code=OS&Product_Code=pg223-224. It's spec sheet gives a load capacity of 25kg but Calum and Mike have tested it with 40kg and it worked fine.





- Ergo Arm.
- Pallet Build - We probably want to build the sections on aluminum pallets to allow for forklift movement.