LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T0900568-v3 *aLIGO* 17 October 2013

Advanced LIGO PSL Installation Plan

Peter King, Rick Savage and Benno Willke

Distribution of this document:
LIGO Scientific Collaboration

This is an internal working note
of the LIGO Laboratory.

Albert-Einstein-Institut
Callinstraße 38
Hannover, D-30167
Federal Republic of Germany
Phone (05 11) 762 2229
FAX (05 11) 762 2784

California Institute of Technology
LIGO Project – MS 100-36
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
FAX (626) 304-9834
E-mail: info@ligo.caltech.edu

Laser Zentrum Hannover
Hollerithallee 8
Hannover, D-30419
Federal Republic of Germany
Phone (05 11) 27 88 0
FAX (05 11) 27 88 100
E-mail: info@lzh.de

Massachusetts Institute of Technology
LIGO Project – NW22-295
185 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 159
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/

0 Preamble

At time of the last update of this document (Oct 2013) the L1 and H1 laser were installed already. Hence the values of different parameters and the test results of those systems (see LIGO-E1100716-v6 for L1 and LIGO-E1200385-v2 for H1/H29) can be used as references during the installation of the third aLIGO PSL.

1 Introduction

The purpose of this document is to outline the stages for installation of the Advanced LIGO PSL.

The document assumes familiarity with various parts of the existing Enhanced LIGO PSL installation. Since a number of components of the Enhanced LIGO PSL will be recycled, it makes sense to start with the decommissioning of the Enhanced LIGO PSL before addressing installation concerns.

Two installation related activities require that special precautions be taken. These are:

- Relocation of the HAM chamber
- Construction of the Laser Area Enclosure

2 Decommissioning the Enhanced LIGO PSL

A number of components of the Enhanced LIGO PSL will be reused in Advanced LIGO. As such it is important that these not be thrown out and that the proper precautions are taken to safeguard their well being. At the time of writing it is expected that these components are:

- The Enhanced LIGO Laser
- The pump fibres
- The cooling water pipes and water chiller
- The reference cavity
- The frequency stabilisation electronics and electro-optics
- The PSL Table
- Three Eurocard crades

2.1 The Enhanced LIGO PSL

The Enhanced LIGO Laser is the 35-W seed laser for the Advanced LIGO Laser. By the start of installation of the Advanced LIGO PSL, the seed laser would have accumulated in excess of 15000 hours. Prior to being shutdown, a full characterisation of the Enhanced LIGO Laser should be done.

2.1.1 Characterization

The following characterization task should be performed before

- note down NPRO settings (current, LD Temperatures, Xtal temperature, …)
- measure NPRO power as close as possible to laser
- measure NPRO power injected into Nd:YVO amplifier and corresponding DC voltage of relaxation oscillation monitoring diode
- note down amplifier parameters (current, LD temperatures, …)
- measure output power of amplifier after the amplifier and before and after PMC
- Make sure the power meter used for this is available for the characterization of the returned laser
- measure noise spectral density of power noise before and after PMC
- measure PZT actuation coefficient input to frequency of 35W laser
- estimate optical losses of reference cavity
- disconnect pump fibres from amplifier head measure slope (power at fibre end vs. pump current of diode)
- Measure amplifier input beam modematching: Place a mirror behind M4 reflecting the transmitted beam hitting the relaxation oscillation diode towards the empty space inside the MOPA. Use a beam profiler or camera to measure the beam waist there. Make sure the same beam profiler/ camera is available for later use for the returned laser. Also make sure this measurement can be exactly replicated later by documenting the setup and all important beam profiler settings.

2.1.2 The Enhanced LIGO laser

After the full characterization the Enhanced LIGO laser has to be prepared for transport and storage. The pump fibres (see next section), the water lines and all the cabling have to be disconnected.

The control-box of the 35W laser, the Laser Diode Box and the NPRO (including its power supply) has to be shipped to Hannover for maintenance and some modifications.

2.1.3 The Pump Fibres and communication fibres

The pump fibres should be properly terminated with a protective end cap to prevent damage to the fibre and the FSMA connectors.

Use a fiber microscope to check the fibers and make a photograph of the fiber end faces trough the microscope.

The pump fibres should then be pulled back to the Laser Diode Room (LDR) for storage whilst the relocation of the HAM chamber and construction of the Laser Area Enclosure (LAE) takes place. Care has to be taken not to bend the fibre ends (the segments NOT protected by the spiral metal tube) more than a corresponding radius of 15cm.

The communication fibres of the TwinCat network should be pulled back and stored together with the associated Ethernet switches etc.

2.1.4 The Cooling Water Lines

The use of distilled water as the coolant for the Enhanced LIGO Laser (and Advanced LIGO Laser) required the use of special water piping. The water piping material is made from a special polyvinyl chloride compound commercially known as LXT. This material and fittings is relatively expensive. It is advisable that as much of the existing cooling line run be preserved as practical.

2.1.5 The Reference Cavity

The words "reference cavity" not only refers to the reference cavity proper but also its vacuum chamber, ion pump, ion pump controller and temperature control hardware. The reference cavity should be stored in a clean area. In particular, two details require some care:

- The reference cavity should remain under vacuum if at all possible (Ion pump in operation). This reduces the likelihood of contamination of its optical surfaces
- Sudden movements of the reference cavity should be avoided so as not to disturb the position and orientation of the vibration isolation stack on which the reference cavity suspension sits.

Even though several of the optics and opto-mechanical components will be replaced, all mirrors, polarisers, waveplates, beamsplitters and their optical mounts should be catalogued and stored for re-use. These could be used as spare parts or for unforeseen measurements during the installation and commissioning phase of the PSL.

2.1.6 The Frequency Stabilisation Electronics

It is planned that the frequency stabilisation electronics will be recycled. These include the Table Top Frequency Stabilisation Servo (TTFSS), the 80 MHz VCO, the Isomet 1205C-843 acousto-optic modulator, the New Focus 21.5 MHz electro-optic modulator and the 21.5 MHz RF photodetector. These should be stored in an appropriate area.

2.2 The PSL Table

The PSL Table will also be recycled. After the Enhanced LIGO PSL is decommissioned the PSL Table should be cleaned and moved to a corner of the LVEA for temporary storage. Prior to installation into the LAE, the PSL Table should be thoroughly cleaned. That is the surfaces of the table be wiped and the table surface be vacuumed to remove any accumulated dust in the tapped holes. After cleaning, the table surface should be covered to avoid any subsequent damage and to keep the tapped holes clean.

3 Refurbish Laser Diode room

Some refurbishment work needs to be performed in the laser diode room:

- The HVAC capacity in the LDR needs to be increased.
- Facility interfaces needs to be checked as upgraded as required
    - Prepare wall feedthroughs and cable trays for two chilled water lines (4 tubes/hoses), pump fibres (7 bundles) and communication fibers

- Electrical power
- Telephone, access control, surveillance camera
- Preparations for intercom to LAE
- Re-establish clean conditions (repair paint, …)
- Install cabinets in Ante room for tools and laser spares
- Ethernet connection to LIGO network

4 Installation of the Laser Area Enclosure

The Advanced LIGO PSL will be housed in the LAE.

4.1 The PSL Table

The installation and subsequent check of the position of the PSL Table is the responsibility of the Input Optics subsystem.

4.1.1 Location of the PSL Table

The position of the PSL Table is the responsibility of the Input Optics subsystem.

4.1.2 PSL Table Legs

The location and installation of the PSL Table legs was the responsibility of the Input Optics subsystem. The placing and grouting of the PSL Table legs will now be done by the PSL subsystem.

4.2 Construction of the Laser Area Enclosure

Construction of the LAE is expected to be handled and managed by Facilities.

4.3 Acceptance of the Laser Area Enclosure

After completion of the LAE, an initial wipe down of the LAE should take place. The dust particle count in the LAE should be monitored.

5 Hazards Review

Prior to the commencement of installation activities, a review of possible hazards likely to be encountered shall be conducted. The Hazards Analysis is currently out for signature approval.

5.1 Work Permit

A work permit shall be submitted for approval prior to commencement of the installation of the Advanced LIGO PSL in the LDR or LAE.

6 The Pump Fibre Bundles and chilled water lines

The pump fibre bundle runs will be installed in their raceway. A qualitative check of the light penetrability of the fibres (with laser pointer or flash light) should be performed. After connection to the pump laser diodes, the power throughput of each fibre bundle – including spares – should be checked. This not only documents the status of the pump fibre bundles but also the pump laser diodes.

7 Installation of the Advanced LIGO Laser

The Advanced LIGO Laser is significantly more complicated than the 10-W Initial LIGO Laser. As such its installation requires a number of stages. The installation takes place in two distinct areas: the Laser Diode Room and the Laser Area Enclosure. The natural installation order is the order of the following sections in this document. However, many of the installation steps can be performed in parallel. A detailed installation plan based on the available person power and expertize should be made prior to installation.

7.1 Installations in the Laser Diode Room

The work in the Laser Diode Room may be carried out independent of other installation related activities within the LVEA.

7.1.1 The Chiller and Cooling Water Diagnostics

The chillers for the Advanced LIGO Laser will be installed in the Laser Diode Room. Prior to connecting the chillers to the plumbing lines, the chillers shall be flushed to remove any contaminants in the chiller (as was the case for the ThermoFisher chiller used for the Enhanced LIGO Laser). The chiller will then be connected to the cooling lines and the chillers will be filled with destilled water. The chillers come with internal diagnostics, such as those for measuring the flow rates and electrical resistivity. In addition the following external diagnostics will be installed:

Differential pressure measurement between the in-line and out-line

(see LIGO-T1100372-v1 for more detail).

7.1.2 The Cooling Water Lines

Ideally installation of the cooling water lines would take place at the same time as the construction of the LAE. Prior to installation of the Advanced LIGO Laser, a pressure test of the cooling lines should be performed to check for leaks or weak joints. If leak tight the water lines should be flushed carefully to make sure that all dirt and residual installation material and chippings are removed.

7.1.3 Pump Laser Diode Equipment Racks

The pump laser diode boxes, power supplies, Beckhoff control computer and the interlock-box will be installed in their 19 inch instrumentation racks and their power supply and water cooling connections will be made. Note that each diode box is quite heavy. Caution should be exercised when mounting the pump laser diode boxes.
Refurbishment of the 35-W Front End Pump Laser Diodes:By the time of installation of the

Advanced LIGO PSL, the pump laser diodes for the 35-W Front End would have been operated for many thousands of hours. The pump laser diode box for the 35-W Front End Laser will be refurbished. As the laser diodes for the H1 system have been exchanged in the late phase of eLIGO these will not be replaced.

The third interferometer will be equipped with a new 35W laser and correspondingly a new Front End diode box.

7.1.4 Pump Laser Diode Testing

All the pump laser diodes for the Advanced LIGO Laser will be tested with the new Control Box temporarily in the Laser Diode Room. These tests will exercise the controls of the laser pump diodes such as the diode current and diode temperature. A special test tool (7 fibres with F-SMA 905 connector, 300W power meter, custom made by neoLASE) is required which will be provided by AEI/neoLASE upon installation.

7.1.5 The EtherCAT and interlock Network

The Advanced LIGO Laser will require installation of a dedicated Ethernet network that will run a proprietary industrial control system, TwinCAT. The same network will be used for the laser interlock system. The required communication fibres and associated network switches need to be installed between the LDR and the LAE.

7.2 Installations in the Laser Area Enclosure

The installation of the high power laser in the LAE will be organized by the Hannover team.

7.2.1 The 35-W Front End Laser

For the 35W laser used in eLIGO already the refurbished NPRO has to be put back into the 35W laser. The modematching of the NPRO to the Amplifier has to be checked according to 2.1.1 laser bullet and adjusted if required. (These steps are not required for the Front End Laser of the third IFO as it was not operated in eLIGO).
The performance of the 35-W Front End Laser should be checked after installation on the PSL Table. The slopes of the for pump diodes (measured at the LAE end of the pump light fibres should be measured. All the controls should be exercised and tested. The output characteristics of the laser should be compared to that given in its test report. The performance and characterisation of the 35-W Front End Laser will be checked with the Diagnostic Breadboard (DBB).

For details on the operation of the Front End Laser see LIGO-T0900646-v1.

7.2.2 The High Power Stage

The High Power Stage weighs approximately 400 kg and will require a small crane to lift it onto the PSL Table surface. Its position on the table is defined in LIGO-T0900610-v5. Once installed on the PSL Table, the cooling water connections should be made and tested for leaks. The flow rate of the cooling water need to be adjusted.

The laser diagnostics such as the power monitors and photodetectors that are displayed by the TwinCAT control system and EPICS should be tested for integrity. Both the high and low power shutters should be exercised and tested. A full test of the interlock system has to be performed (LIGO-T1000005-v2).

The alignment of the 35-W Front End Laser output into the High Power Stage should be checked. The transmission and isolation of the high power Faraday isolator should be measured and recorded. Note that strong magnets are used in the high power Faraday isolator so caution must be exercised whilst moving metallic tools near by.

The alignment and controls for the High Power Stage should be exercised, tested and optimised.

Full characterisation of the High Power Stage will be done with the Diagnostic Breadboard. Regular diagnostic tests are expected to be performed during detector maintenance periods.

For details on the operation of the High Power Laser see LIGO-T0900641-v4

7.3 Injection Locking Electronics

Once functional verification of both the 35-W Front End Laser and the High Power Stage as standalone lasers has been completed, testing the injection locking electronics can proceed. The control loop transfer function will be measured and compared with either the design or a reference measurement to insure that nothing was damaged during shipping or installation.

An area close to but outside the Laser Area Enclosure needs to be reserved for installation of the instrumentation racks within the LVEA (see LIGO-T1200085-v2 for a top level layout). Care needs to be taken so that no other installation related activity, such as craning over large equipment items or forklift operations, damages the racks and the PSL electronics installed in those racks.

8 Installation of the Advanced LIGO PSL

8.1 The Diagnostic Breadboard

The purpose of the Diagnostic Breadboard is to check the performance of the Advanced LIGO Laser, the PSL and the beam from the Input Optics. It will be one of the first items installed on the PSL Table and can be carried out in parallel with installation of the High Power Stage. Its position on the table is defined in LIGO-T0900610-v5.

The EPICS and real-time controls for the Diagnostic Breadboard will be installed in the LVEA racks (see LIGO-T1200085-v2), tested and exercised. The availability of various signals from the Diagnostic Breadboard to the Advanced LIGO data acquisition system will be checked.

For details on the operation of the Diagnostic Breadboard see LIGO-T0900133-v2 and LIGO-T0900579-v1.

8.2 The Pre-modecleaner

Installation of the pre-modecleaner (PMC) will require positioning the PMC chamber on the PSL Table. Its position on the table is defined in LIGO-T0900610-v5. Once installed, the PMC will be mounted inside the chamber. The output of the High Power Stage will be mode matched to the PMC. The PMC visibility will be recorded.

The EPICS controls for the PMC control electronics will be tested and exercised. The PMC servo transfer function will be measured and recorded.

8.3 The Frequency Stabilisation

The reference cavity will be moved from storage and installed onto the PSL Table. Its position on the table is defined in LIGO-T0900610-v5. This will be a heavy load and will require some caution.

The beam sample for the frequency stabilisation will be aligned and double-passed through the frequency shifting acousto-optic modulator (AOM). The double-passed output will then be mode matched to the reference cavity. The reference cavity visibility will be measured and recorded.

The EPICS controls for the frequency stabilisation electronics will be tested and exercised. The frequency servo transfer function will be measured and recorded.

8.4 The Power Stabilisation

Prior to installation of the power stabilisation photodetectors on the PSL Table, the power of the beam sample to be used will be measured, and if necessary attenuated to a level appropriate. This will help insure that the power incident on the photodetector does not damage it. The in-vacuum photodetector for the outer power stabilization loop will be installed together with the IO HAM2 installation. The position of the ISS photodetector box on the table is defined in LIGO-T0900610-v5.

The AOM used for the power stabilisation will be aligned for optimum performance. This should be done prior to mode matching the beam into the PMC. The RF drive levels to the AOM will be measured and adjusted to the appropriate level.

The EPICS controls for the power stabilisation servo electronics will be exercised and tested for functionality. The power stabilisation servo transfer function will be measured and recorded.

Once all the PSL control servos have been installed and been put through their initial individual checks, the performance of the PSL will be tested in both the high power (~200W) mode and the low power mode (~16W).

9 Walk Around

Upon completion of the installation, a walk around of the PSL is to be conducted. This is for the benefit of the local cognizant site staff and the site laser safety officer.

10 Completion of Installation

At this point all the major hardware items for the PSL would have been installed and given a preliminary test. Commissioning of the PSL can now commence, along with training of the local cognizant site staff.