



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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LIGO

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Arm Length Stabilisation Acceptance Documentation

Bram Slagmolen, Peter Fritschel

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1 Requirements documentation

The design requirements document must be brought up to date, and pointers to background material, analyses, etc. added to the Requirements document. Pointers to prototyping endeavors including testing results if they are not superseded by subsequent testing should be included here.

The design of the Arm Length Stabilisation started with a review for the best implementation for such a system, as discussed in Adv. LIGO Arm Cavity Pre-Lock Acquisition System ([T080139](#)).

- a. *Design Requirements Document (DRD):*
 - a. Adv. LIGO Arm Length Stabilization Design ([T0900144](#))
 - b. Arm Length Stabilization VCO Noise requirements ([G1000703](#))

2 Design overview and detailed design documentation

- a) *Final Design Document (FDD): must bring the FDD up to date.*

ALS Baseline Top Level Diagram ([D1201234](#))

- b) *Review reports:*

- *cite the final design review committee's report*
- *cite the design team's response to the final design review (note that any resulting changes to the design should have been incorporated into the FDD).*

Review Report Interferometer Sensing and Control Final Design : [T1000334](#)

Responses: found on page 15, 16 and 17; all questions were addressed.

- c) *Supporting design documents: models, analyses, specifications, etc. If not applicable, then state so.*

aLIGO, ISC, ALS ([E1200169](#)) – This is the top of the ALS document tree.

Nominal ALS Frequencies ([T1300883](#))

Arm Length Stabilization (ALS) Vertex Detection System ([T1400317](#))

Simple diagram of ALS optical layout ([D1400372](#))

Arm Length Stabilisation - FIBRE Phase-Locked-Loop ([T1200429](#))

ALS mode matching solutions – ISCT1 ([T1300499](#))

- d) *Drawings: cite the top level assembly drawing for each major assembly or subsystem. In the DCC, all subsidiary drawings (sub-assemblies and part drawings) must be linked in a drawing tree manner.*

Adv. LIGO Arm Length Stabilisation - Vertex Layout Overview ([T1000555](#))

aLIGO, ISC, ISCT End ([E1200162](#))

aLIGO, ISC, ISCT1 ([E1200158](#))

ALS Beams @ HAM1 ([L1200282](#))

Vertex ISC Electronics Cable Layout ([D1200666](#))

EtherCAT System Diagram ([D1100683](#))

End Station ISC Electronics Wiring ([D1100670](#))

- e) *Bill(s) of Materials (BOM): cite any collected BOMs. If the BOMs are only to be found on the Assembly and Sub-Assembly drawing sheets, then state so.*

ALS Components BOM ([E1300483](#))

- f) *Interface control: cite any documents (such as RODAs) with interface definition/control and/or cite the relevant sections of the DRD and FDD.*

The ALS is interfaced with the PSL table. There are two main interfaces, 1) with the Reference Cavity transmitted beam and 2) 1W pick-off from the main laser beam. These interfaces are shown in:

PSL Table Layout for Advanced LIGO ([D0902114](#))

- interface 1) is via M29
- interface 2) is via IO_MB_M2 (prior the main EOM)

- g) *Software: cite any software design description documentation. If not applicable, or not available, then state so.*

The ALS automation is done via the Beckhoff system. The full EtherCAT libraries can be found at [E1200381](#).

Specific TwinCAT Library for

- ALS State Machine ([E1300772](#))
- PZT Mirrors ([E1200628](#))
- ALS Laser ([E1200632](#))
- ALS Communication ([E1300430](#))
- ALS Laser Locking ([E1300482](#))
- ALS PDH Locking ([E1300706](#))
- ALS Frequency ([E1300767](#))
- Fiber Distribution ([E1300776](#))
- Fiber Polarization Correction ([E1300777](#))

- PLL for Low Noise VCO ([E1300805](#))
- SHG Status Monitoring ([E1300875](#))

h) Design source data:

- *Confirm that all mechanical design CAD models are in the SolidWorks/PDMWorks vault, or explain what is not and why.*
- *Confirm that all electronics design CAD models (schematics and PWB layouts) are backed up and available on LIGO Lab archives, or explain what is not and why.*

Not applicable as the individual items have been reviewed.

3 Materials and fabrication specification

Any special materials, or treatment of materials including preparation for in-vacuum use; this may be integrated into the Design documentation.

Most components are commercially available. Only some bases and mounts are LIGO design, but are clearly listed in the table assembly filecards.

4 Parts and in-process spares inventoried

All elements of aLIGO must be recorded in the ICS or in the DCC using the S-number scheme. As-built modifications for parts or assemblies should be found here.

The optical tables layouts on which all the ALS system is assembled are in the DCC, see 2d (and have been review as per [E1400395](#)).

All ALS components are listed in the ALS Components BOM ([E1300483](#)).

Only the ISC in-vacuum components are listed in the ICS.

5 Assembly procedures

All assembly procedures must be in the DCC and annotated or updated for lessons learned. Storage, if used, should be described here along with procedures to maintain the equipment in good condition (e.g., purge frequency). Transportation procedures and cautions must be noted.

All ALS related in-air tables have already been reviewed ([E1400395](#))

ALS Fiber Distribution Assembly ([D1200136](#))

6 Installation procedures

All installation procedures must be in the DCC and annotated or updated for lessons learned.

All ALS related in-air tables and their installation have already been reviewed ([E1400395](#)).

7 Test documents

Test rationale, plans, and data for each unit must be documented as described in M1000211. That tree structure should be pointed to by the overall tree structure laid out in this Acceptance prescription. The top-level objective is to make clear how the measurements performed, which often will not directly measure a required performance parameter, give confidence that the subsystem will fulfill the requirements.

ALS Fiber Distribution Box Test Results ([E1201087](#))

Executive Summary of the One Arm Test ([L1200261](#))

Executive Summary of the LHO HIFO-Y Test ([L1300176](#))

ALS Noise Measurements and Model for HIFO-Y ([T1300688](#))

Achieving Resonance in the Advanced LIGO Gravitational-Wave Interferometer ([P1400105](#))

8 User interface software

User interface software, and the test routines indicating proper functioning of the software, must be described in words and have code under configuration control (SVN). Watchdog and Guardian routines must also be treated in this way.

TwinCAT Library for ALS State Machine ([E1300772](#)), and all code is in the aLIGO SVN repository.

9 Operation Manual

*A manual appropriate for operators, written in accordance with M1200366, covering setup/initialization, check-out, operating instructions, calibration, maintenance, **operations spares plan**, storage/transport and troubleshooting. It must be accessible from standard user screens.*

ISC End Station User's Manual ([T1300903](#)).

10 Safety

Safety documentation must be in the DCC for all phases of the subsystem development, including any needed for normal use or foreseen maintenance/repair scenarios.

SOP for Arm Length Stabilization Setup in LVEA and VEA at LHO ([M1100040](#))

SOP for operating the Arm Length Stabilization at LLO ([M1300551](#))

Temporary SOP for LLO Arm Length Stabilization Assembly ([M1300500](#))

Prometheus Product Line, User's Manual ([T1000643](#))

The following safety documents shall be referenced for any maintenance or repairs:

- *LIGO Observatories Operations Safety and Enviro Protection Manual - M980242-v2*
- *LIGO Work Permit Guidance - M050194-V2*
- *LIGO Lab Electrical Safety Policy - M1200022-v1*
- *LIGO Lab System Safety Plan - M950046*