



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

*LIGO Laboratory / LIGO Scientific Collaboration*

LIGO-T1300091-v11

*ADVANCED LIGO*

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**Input Optics Acceptance Documentation:  
Faraday Isolator – L1, H1**

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## 1. Introduction

The top level DCC entry for the aLIGO Input Optics acceptance documentation is [E1201013](#). The acceptance documentation for the Faraday Isolator is linked to this entry under related documents, following this structure:

- [LIGO-E1201013](#): aLIGO Input Optic
  - [LIGO-T1300091](#): IO Faraday Isolator
  - [LIGO-T1300123](#): IO Faraday Isolator Requirements and Design
  - [LIGO-T1300086](#): IO Faraday Isolator Material and Assembly Documents
  - [LIGO-T1300466](#): IO Faraday Isolator Assembly Procedures
  - [LIGO-T1300469](#): IO Faraday Isolator Installation and Alignment Procedures
  - [LIGO-T1300125](#): IO Faraday Isolator Testing Documentation
  - [LIGO-T1300441](#): IO Faraday Isolator Hazard Analysis

In sections 2 to 11 below we address the 10 items listed in section 1 of [M1100282](#) “Acceptance Deliverables and Criteria for Advanced LIGO”, with information appropriate to the IO Faraday isolator. There will be separate acceptance documents for L1, H1 and H2, linked under the same top level DCC file card [LIGO-T1300091](#).

The H2 Faraday will be assembled and tested sometime during September 2013, either at LLO in the HPLF or at UF. Making sure it all works fine, it will then be disassembled and shipped to LHO, to be stored according to [LIGO-T1200567](#) – Input Optics IO Long Term Storage for the 3rd aLIGO Interferometer.

## 2. 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 Pointers to prototyping endeavors including testing results if they are not superseded by subsequent testing should be included here.*

This documentation is listed under [LIGO-T1300123](#): IO Faraday Isolator Requirements and Design

- a. *Design Requirements Document (DRD):* [T020020-v2](#)
- b. *Supporting documents (background material, models, analyses, ...)*
  - [LIGO-T060267](#): Upgrading the Input Optics for High Power Operation
  - [LIGO-G060361](#): Modulators and Isolators for Advanced LIGO
  - [LIGO-T060025](#): Analysis of Stray Magnetic Fields from the Advanced LIGO Faraday Isolator
  - [LIGO-P1100095](#): High vacuum compatible high power Faraday isolators for gravitational-wave interferometers
- c. *Prototype tests*
  - [LIGO-T070021](#): Status of High Power Measurements in Faraday Isolators
  - [LIGO-G080205](#): E-LIGO Input Optics Characterization and Performance

- [LIGO-P1100056](#): Characterization of thermal effects in the Enhanced LIGO Input Optics

### 3. Design overview and detailed design documentation

The Faraday isolator (FI) is located between the input mode cleaner and the power recycling mirror inside the HAM2 table. Its location and the beam routing inside HAM 2 are described in [T1300021](#). The FI separates the beam going into the interferometer (red in Figure 1) from the beam (green) being reflected from the power recycling mirror.

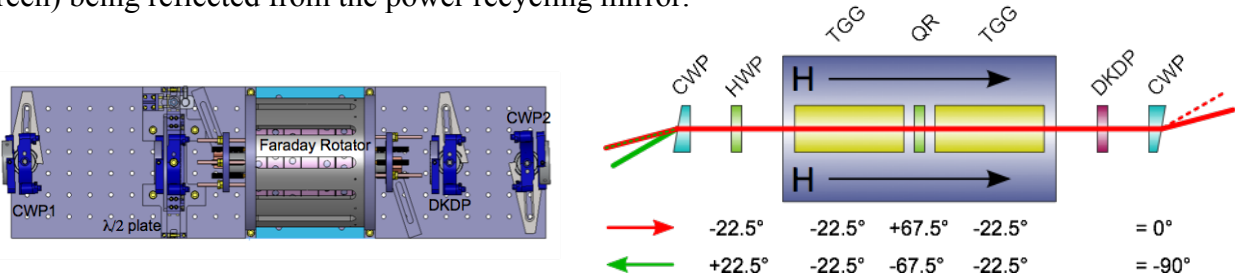


Figure 1: The left shows a drawing of the final assembly and the right a schematic of the FI

It consists of two TGG crystals and a quartz rotator inside the magnet. It also uses a motorized half-wave plate to optimize the polarization rotation between the two calcite wedge polarizers. Note: The thin film polarizer (TFP) is no longer required for the FI. It has been removed to reduce the losses and to avoid thermally induced beam steering in the return beam.

Documentation related to Final Design of the L1-Faraday isolator is listed under [LIGO-T1300123](#): IO Faraday Isolator Requirements and Design

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

- [LIGO-T0900386](#): Advanced LIGO Input Optics Final Design Document

b) *Review reports:*

- *cite the final design review committee's report:*

- [LIGO-L1000062](#): Review Committee Report on the Input Optics FDR Documents

- *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).*

- [LIGO-G1000002](#): Input Optics Response to FDR Review Committee Questions on Technical Documentation
- [LIGO-G1000007](#): IO responses to the IO FD review committee comments and questions on specifications and drawing documentation

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

**The Final Design Review for the Faraday isolator was at the Long-lead Procurement Readiness Review.** The documents associated with this review are:

- [LIGO-T080075](#): Input Optics Procurement Readiness
- [LIGO-L080041](#): Review committee questions to IO regarding the Longlead procurements

## Final Design Review and IO Responses

- [LIGO-L080069](#): Review committee report on the Input Optics Long-lead procurements Final Design Review

## Other Important Design Documentation:

*(The input Faraday isolator had a full review at the Preliminary Design stage, and the PDR documents below together with T060267 and G060361 from Section 2.a above present in-depth background material on the design of the Faraday isolator as a whole).*

- [LIGO-T060269](#): Advanced LIGO Input Optics Subsystem Preliminary Design Document
- [LIGO-T070248](#): Advanced LIGO Input Optics Preliminary Design Review Report
- [LIGO-T080079](#): Response to the Advanced LIGO Input Optics Preliminary Design Review Report

*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.*

## Drawings Document Tree:

- [LIGO-D1000332](#): ALIGO IO L1 FI ASSEMBLY
- [LIGO-D1000333](#): ALIGO IO H1 FI ASSEMBLY
- Use D1000332 or D1000333 for aLIGO 3<sup>rd</sup> IFO FI assembly. Note: some parts will need to be custom made once 3<sup>rd</sup> IFO beam heights are known.

*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.*

- BOM under [D1000332](#) (L1), [D1000333](#) (H1) , [T1500097](#) (3<sup>rd</sup> IFO)
- SW Vault files: D1000332 (L1), D1000333 (H1)

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

There are no RODAs applicable to the IO Faraday isolator.

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

There is no software design description documentation available for the Faraday isolator.

*h) Design source data:*

*- Confirm that all mechanical design CAD models are in the SolidWorks/PDMWorks vault, or explain what is not and why.*

All mechanical design CAD models are in the vault.

*- 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.*

Block diagram of the IO electronics:

- [LIGO-D1100909](#): Input Optics Electronics Layout

Document tree for picomotors controlling the HWP of the Faraday (from ISC):

- [LIGO-E1200361](#): aLIGO, Slow Controls, Controllers, Picomotor

#### 4. 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.*

Documentation related to materials and fabrication of the L1-Faraday isolator is listed under [LIGO-T1300086](#) IO Faraday Isolator Material and Assembly Documents.

1. L1 FI Optics List (installed, spares, specifications, vendor info, certifications)

[LIGO-T1300458](#): Optics List for IO Faraday isolator

Optics Specifications and Certifications

1. [LIGO-E080125](#): aLIGO TGG crystals for Input Optics Faraday isolator
2. [LIGO-E0900330](#): ALIGO IO CALCITE WEDGE POLARIZER
3. [LIGO-E1100122](#): Quartz Rotators for aLIGO Input Optics Faraday isolators
4. [LIGO-E1100222](#): aLIGO HWP for IO PSL and HAM2 Tables
5. [LIGO-C1202707](#): aLIGO TGG crystals for Input Optics Faraday isolator - Vendor Data
6. [LIGO-C1202732](#): Calcite Wedge Polarizer for Faraday Isolator - Vendor Data
7. [LIGO-C1202706](#): Quartz Rotators for aLIGO Input Optics Faraday isolators - Vendor Data
8. [LIGO-C1202731](#): aLIGO HWP for IO PSL - Vendor Data
2. Documentation related to Baffles for the Faraday isolator is linked from the top level DCC link [IO HAM2](#) via [LIGO-E1200589: aLIGO, IOO, Baffles](#).
3. Treatment of Materials - Cleaning procedures and waivers:
 

[LIGO-E1300458](#) Cleaning Procedures and Waivers for IO Faraday Isolator

  1. [LIGO-E1100439](#) General Optics Cleaning Procedure
  2. [LIGO-E960022](#) LIGO Clean and Bake Methods and Procedures
  3. [LIGO-E960050](#) LIGO Vacuum Compatible Materials List
  4. [LIGO-E0900047](#) LIGO Contamination Control Plan
  5. [LIGO-L070089](#) Request for advice/waivers on some Input Optics elements
  6. [LIGO-L070091](#) VRB Response to IO Group request for waivers.
  7. [LIGO-L1100046](#) VRB request: no baking for optics?
  8. [LIGO-L1200067](#) VRB Reply to Optics Cleaning and Baking proposal. (L1100046)

## 5. 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.*

1. FI Assembly ICS location [ASSY-D1000332-001](#) (L1), [ASSY-D1000333-1](#) (H1)
2. FI Optics in ICS, including spares:
  1. [TGG Crystals](#)
  2. [Calcite Wedge Polarizers](#)
  3. [Quartz Rotators](#)
  4. [Superpolished HWP](#)
  5. [DKDP](#)
3. Electronics in ICS – N/A

## 6. 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.*

Documentation related to assembly procedures for the IO Faraday isolator is listed under [T1300466](#). These are the following:

- [LIGO-E0900301](#): IOO Faraday Isolator Assembly and Certification Procedures
- [LIGO-E1300422](#): ALIGO IO Faraday Isolator Mechanical Assembly Procedure
- [LIGO-E070200](#): ELIGO FR Magnet Assembly Procedure
- [LIGO-E1000110](#): aLIGO FR Magnet Assembly Hazard Analysis (listed for completeness)

## 7. Installation procedures

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

Documentation related to installation and alignment procedures for the IO Faraday isolator is listed under [T1300469](#).

- [LIGO-T1000097](#): IO Installation Plan
- [LIGO-T1300327](#): Alignment of the In-Vacuum Input Optics (supersedes [T0900267](#)).

## 8. 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.*

Test documents for the IO Faraday isolators can be reached from the aLIGO Testing and Commissioning Documentation DCC entry [LIGO-E1000369](#) following the structure:

- [LIGO-E1000369](#): aLIGO Testing and Commissioning Documentation
- [LIGO-E1300439](#): aLIGO IO Testing and Commissioning Documentation
- [LIGO-T1300125](#): IO Faraday Isolator Testing Documentation
  - [LIGO-E0900301](#): IOO Faraday Isolator Assembly and Certification Procedures
  - [LIGO-E080130](#): Test Plan and Acceptance Criteria for the Advanced LIGO Faraday Isolator
  - [LIGO-T1200517](#): Input Optic initial High power testing at LLO
  - [LIGO-T1300124](#): Test Results for aLIGO IO Faraday Isolators
  - [LIGO-E1300484](#): Test Results for the IO Faraday Isolator - L1
  - [LIGO-E1300485](#): Test Results for the IO Faraday Isolator - H1
  - [LIGO-E1300572](#): Test Results for the IO Faraday Isolator - H2
 

“Test Reports” uploaded as main documents for E1300484 (L1) and E1300485 (H1). Test results for H2 are summarized under E1300572.
  - [LIGO-T1300476](#): Operation Manual for the IO Faraday Isolator. (-v3 updated)

## 9. 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.*

There is no user interface software maintained by IO for the control of the FI picomotor. The document tree for the slow control EtherCAT Software maintained by ISC is

- [LIGO-E1200381](#): aLIGO, Slow Controls, EtherCAT Software

## 10. Operation Manual

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

- [LIGO-T1300476](#): Operation Manual for the IO Faraday Isolator (version v3 updated)
- [LIGO-T1200496](#): MPC1 Motorized Polarization Controller Manual (from ISC).

## 11. 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.*

Documentation related to safety and hazard analysis for the L1-Faraday isolator is listed under [T1300441](#).

- [LIGO-E1000110](#): aLIGO FR Magnet Assembly Hazard Analysis
- [LIGO-L0900192](#): AdvLIGO IO Hazard Analysis
- [LIGO-L0900202](#): IO Hazard Analysis Table