



*LIGO Laboratory / LIGO Scientific Collaboration*

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**Review Report  
Final ISC Design  
for the A+ Filter Cavity**

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# 1 Executive Summary

## 1.1 Findings

All action items and recommendations from the preliminary design review have been addressed. No new major issues have surfaced during the final design review. We consider the review process for the ISC A+ filter cavity design complete and recommend to proceed.

## 1.2 Actions

None.

## 1.3 Recommendations

### 1.3.1 Remove the steering optics in HAM8

Since there is no need for in-vacuum detectors anymore, one could eliminate the steering optics that guides the beam out of the viewport, by propagating the transmitted beam straight through.

## 2 Technical Scope

### 2.1 Scope

The scope of this report is to review the final ISC design of the A+ filter cavity, described in in [E2000165](#) and supporting documents.

Previous documents can be found at [E1900221](#).

Supporting documents are:

- E2000155: [OPO M1 and M2 cavity mirrors for lower threshold and improved transmission](#)
- E1900301: [A+ ISC components and procurement list \(for Frequency Dependent Squeezing\)](#)
- D1900281: [FDS-SQZ optics table layouts](#)
- T1900649: [Frequency Dependent Squeezing Final Optical Layout](#)
- E1900201: [aLIGO, FDS-SQZ, Electronics Block Diagram](#)
- E2000069: [Coated Substrate, aLIGO+ Filter Cavity Input Mirror FC1](#)
- E2000070: [Coated Substrate, aLIGO+ Filter Cavity End Mirror FC2](#)
- T1800447: [Design Requirement Document of the A+ filter cavity and relay optics for frequency dependent squeezing](#)
- T2000138: [Fundamental Bilinear A2L Requirements on ASC for the A+ filter cavity](#)

The full scope of A+ ISC also includes additional sub-subsystems for adaptive wavefront compensation (AWC), low-loss Faraday isolators (FI), and the balanced homodyne readout (BHD) as well as the integrated electronic controls infrastructure (ISC CDS). These elements will be reviewed separately in future.

### 2.2 Charge to the Review Committee

1) Please refer to the check list of general LIGO review criteria in section 11.3 of [LIGO-M1500263](#); additional guidance specific to A+ Project design reviews can be found in [LIGO-M1800239](#).

2) Evaluate the FDR to insure that it captures all relevant criteria for success. These should include such factors as:

- Clarity of presentation and operating context
- Compatibility with the planned A+ optical and mechanical configuration
- How the action items of the PRD review were addressed
- Compatibility with existing Advanced LIGO infrastructure
- Provisions for installation, testing, commissioning and future maintenance

3) Please investigate and comment on the degree to which requirements for the filter cavity and relay optics may depend on uncertain or optional features of these related components. Identify what provisions, if any, may be required to insure that the designs can proceed independently without risk of incompatibility.

4) Summarize comments and recommendations in a report addressed to Dennis Coyne (LIGO Chief Engineer) and Michael Zucker (A+ Project Lead). Any panel requests for action should be clearly categorized as follows:

- Required change: Panel approval is conditional on implementation.
  - Recommendation: Panel advises but does not require adoption.
- a) Comment/Suggestion: Panel requests the design team investigate and consider, e.g., a potential improvement, or wishes to convey other helpful information.

### 3 Review Comments and Questions

Here is a collection of questions and answers which were investigated during the review process.

1. **MZ: Mike made a comment about the placement of the HAM8 transmission table that makes me realize that the in-vacuum path is unnecessary if we don't have QPDs.. We can remove some vestigial complexity. We can just have the beam fly out the window and have the table at the +Y side. That saves 3x 2" optics + mounts and the extension on that HAM.**

Lee: HAM8 Transmission beam. The current drawing D1900281 shows the beam relaying in vacuum out the side. We could just have the beam fly out the +Y window and down the periscope. If we don't install some of the in-vac components, it will be much harder to add in-vac diodes in the future if we need them. Thoughts on simplifying the layout and using the transmission table at +X?

DS: I don't think it is very likely that we need in-vacuum detectors in HAM8, so there is no need to make it easy for future upgrades. I assume you think of having no steering optics inside and shoot the beam straight through HAM8? One thing to make sure is that this beam actually exist through the rear window taking into account manufacturing tolerances of the HAM doors and chambers as well possible chamber orientation inaccuracies.

Lee: Word from Chandra is that the viewports are good to 1/4" of drawn location. We'll check solidworks and likely update the layout to make HAM8 pretty barren.

2. **Lee: 40MHz 532 EOM for FCGS PDH. Need resonant EOM or not? Large sidebands are good for this purpose, but worry about 2F content on diodes, maybe 2F is going to be large no matter what, so might as well make SNR good. If we go with broadband then we have flexibility, but currently no reason why 40MHz wont work well.**

DS: Worrying about 2f is good, but I am afraid you may be in a no win situation here. With a small modulation index you have a lot of DC light that doesn't add much, with a high modulation index you may have to reduce the light power on the detector, but the SNR may be similar.

In iLIGO we tested our AS port photodiodes at 100mW with small modulation and they worked fine. However, the actual diodes couldn't handle much more than 25mW when most of the power was in 2f.

So a few mW shouldn't cause problems.

Lee: Resonant it is then.

3. **Lee: 300m fiber to HAM8 for any transmission injection and alignment beam source. I've designed in that we will pipe a long fiber to have beam for transmission injection into the FC. Originally, this was to provide a convenient means of mode matching signals. Here at MIT we now use an injection method where we lock the cavity and see the power buildup and fit everything out. Thoughts on if we should just use a separate non-phase locked laser for alignment and forgo the option of transmission injection. I worry if we don't run it now, then feeding a fiber through 300m of conduit will not work in the future.**

DS: I have a hard time seeing this to be essential ever. We use communication fiber for the ALS system in the end station. So, we could probably send 1064nm to the FC end station, if we change our minds later.

Lee: Sounds like we'll remove it and add it in that unlikely case, then.

4. **SD: Will the addition of the inspection path limit the aperture for the normal squeezing injection path? (Either with a beam diverter or fixed mount mirrors?)**
  
5. **LB: I am wondering if we should plan to use SQZT6 as SQZT7 at LLO and avoid buying a new table/legs for SQZT7 right now, given potential issues with shipping and also work needed to put a new table + enclosure together. Are we concerned about having a different table size at the two sites? (LHO has an existing 4x8 table that can be used as SQZT7). Alternatively, we can just wait ~ 1 month and see what happens.**

DS: There are 2 unused 4x8 optics tables at LHO which are left from H1. In the past, we decided it was easier to buy new tables for L1 rather than to ship existing ones.

At LHO (not LLO), we also need [3" spacers](#) to bring the table height to the desired height.

Current tables: Newport RS4000, 4'x'8'x 12" and Rigid Supports: Newport NN4-28-TC

#### **LB: 1" vs 2" question**

DS: Let's use 1" in HAM7.