LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Advanced LIGO Input Optics Preliminary Design Review Report

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LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Report on the Preliminary Design Review of the Advanced LIGO Input Optics

Participants:

- Dave Reitze, Dave Tanner, Guido Mueller, Rick Savage, Muzammil Arain, Volker Quetschke, David Shoemaker, Luke Williams

Review Committee:

- Dennis Coyne, Eric Gustafson, Gregg Harry (chair), Peter Fritschel, Peter King, Mike Smith, Calum Torrie, William Tyler

Documents Presented and Discussed

Reviewed Documents:

- Revised Preliminary Design Requirements Document T020020-01-D
- Input Optics Subsystem Preliminary Design Document T060269-02-D
- Input Optics Test Plan T070199-00-D
- Complex Modulation T070197-00-R
- Generic Input Optics Requirements and Standards E010170-00-D

Presentation Viewgraphs

- Input Optics Preliminary Design Slides G070591-00-D

Charge and Findings:

1) Review the requirements for the IO layout and the power control, EOM's, mode cleaner, and the mode matching telescope. Determine whether the derived requirements are complete, correct, traceable to fundamental science/performance requirements and documented. Advise whether proposed requirement values are appropriate. If needed, recommend additional requirements to be specified (e.g. design or functional features), and recommend other appropriate actions. Some specific points to consider are:

- *definition of the scope and objectives*
- *delineation of interfaces (particularly with PSL, SUS, and SYS ENG)*

Both the PSL and IO teams need to define their requirements for the PSL table and agree on a distribution of space on the table. This will be especially important if it is determined that there is not enough space on the table as currently conceived and a larger table will be needed. A particular question was whether such long beam paths were necessary in the IO path on the PSL table. The

IO team should communicate with Mike Smith about a possible off axis design for mode matching that could help reduce the need for long beam paths.

- *performance requirements*

Coating absorption, scatter, and high power effects in the Input Mode Cleaner over long periods of operation should be examined. It then needs to be determined if the initial LIGO REO tantala/silica coatings are sufficient. The IO team should take advantage of vents during Enhanced LIGO work to look at the Initial LIGO mode cleaner and test mass optics, and especially the coatings, to see what can be learned. Then a determination will need to be made about whether REO tantala/silica dielectric coatings will be sufficient for the Advanced LIGO Input Optics, whether LMA tantala/silica will work, or if research will be needed to improve the coatings. Any need for further coating research should be communicated as soon as possible to the LSC Coating Working group and a plan developed to develop coatings that will meet IO requirements.

- *functional or feature requirements*
- *physical and environmental requirements*
- *documentation*

All documents reviewed need to be submitted and archived in the DCC. T070199-00-D, T070197-00-R, E010170-00-D, and G070591-00-D are missing.

There is a need for a list of critical components needed for the Input Optics and where, how, and when they will be obtained.

In addition, a hazard and risk assessment and matrix for IO needs to be prepared and submitted to the Safety Steering Committee for review and comment. One goal of this review will be to find ways to reduce the number of items that will require review and disposition by the LIGO Directorate.

- *testing criteria*

The input optics team needs to work with CDS and in particular Rich Abbot to develop a plan for testing the electronics needed in IO.

The Input Optics Test Plan, T070199-00-D, is a very good “Acceptance Test Plan” and the committee complements the IO team on it. In addition to this plan, a documented plan for tests on components and subassemblies, to be performed before they are released to the installation teams, is also needed. A checklist of things that need to be checked either at Florida or at the sites before installation will be sufficient for this.

2) Review the preliminary designs for consistency with the requirements and determine if they have been sufficiently advanced/tested in order to proceed with a final design. In particular, determine whether the designs are ready to proceed to fabrication of the planned Enhanced LIGO components. Where competing designs or technologies are/were under consideration, review the adequacy of the decision making process for selecting a final design.

The reliability of the picomotors to be used to rotate the waveplate for power control while operating in vacuum will need to be evaluated during Enhanced LIGO.

There are many aspects of the design and requirements of baffles throughout the input optics that need to be more fully developed. The IO team did say that they did not have a preliminary design for baffles ready for review, and suggested that they be given a few more months to finalize one. This is the result of a recent change in scope for IO. A separate and specific Preliminary Design Review just on baffling would then be performed. The committee supports this approach.

A few questions this committee had about baffles that should be addressed at the proposed PDR are:

- What tolerances will the placement of the baffles need and will they have relative to the location of the beam?

- What frequency noise is expected from scattered light off of the baffles?

- How will the decision on whether to have smaller baffles on the seismic table as opposed to larger baffles connected to the vacuum tanks be made?

- What are the normal modes of the baffles and will they cause low frequency resonances in the SUS structures?

- How will the choice of materials for the baffles be made? Does there need to be a research plan to look at silicon carbide and/or other potential baffle materials?

3) Review the preliminary assembly, alignment, and installation plans for completeness. In particular, determine whether the plans are sufficiently advanced for the fabrication and installation of Enhanced LIGO components.

The committee recommends that the IO team should have a representative on the LIGO Safety Committee and it supports Antonio Lucianetti for that.

4) Verify that the final design plan, including test or development plans, acknowledges and adequately addresses areas of concern. Identify areas of relatively high risk with respect to technical, cost, or schedule issues and review the adequacy of mitigation plans to address those risks.

The IO team needs to work with the 40 meter team to determine the long term stability of the Mach Zender modulation scheme in use at the 40 meter. This information should be incorporated into the test plans for the monolithic Mach Zender setup at Florida, and especially should be used to determine what priority to set on this research.

There needs to be a plan to study the conduction of the TGG holder in the enhanced LIGO Faraday Isolator to see if further improvements will be needed for Advanced LIGO to reduce the temperature dependence of the isolation factor.

The IO team should develop a plan to study the initial LIGO step control of input power to determine if the same hardware as used in initial LIGO will still be adequate in Advanced LIGO. And if not, what needs to be improved.

The committee identified two schedule risk issues that need to be examined and clarified. First the supply chain for critical components needs to be documented and the risks of delays or possible failures should be determined. This can be addressed as part of the documentation of critical components requested above under Documentation. Second, the role of the Institute for Applied Physics in Russia in supplying critical components needs to be better specified and whether there is any schedule risk associated with its role determined.

5) Verify that safety and cyber security concerns have been identified and adequately addressed.

The committee found no inadequacies in cyber security.

Preliminary Design Review Checklist from M050220-02

System Design Requirements, especially any changes from the DRR – OK other than coating issues above.

Subsystem and hardware requirements, and design approach – OK other than the step power control, Mach Zender modulation scheme, and baffling issues above.

Justification that the design can satisfy the functional and performance requirements – OK other than Faraday Isolator and electronics testing issues above.

Resolution of action items from DRR – OK other than baffling issues above.

Interface control documents – OK other than PSL table issue above.

Instrumentation, control, diagnostics design approach – OK other than Faraday Isolator, power step, and Mach Zender modulation issues above.

Fabrication and manufacturing considerations – OK other than IAP issue above.

Preliminary reliability/availability issues – OK other than coating and Mach Zender modulation issues above.

Installation and integration plans – OK other than PSL table issue above.

Environment, safety, and health issues – OK other than the hazard and risk assessment and matrix, and safety committee issues above.

Human resource needs, cost, and schedule – OK other than IAP issue above.

Any long-lead procurements – OK

Technical, cost, and schedule risks and planned mitigation – OK other than IAP issue above.

Test plan overview – OK other than electronics, Mach Zender modulation, power step control, and coating issues above.

Planned tests or identification of data to be analyzed to verify performance – OK other than request for test plan in prototyping stage.

Identification of testing resources – OK

Test and evaluation schedule, prototype, and production – OK other than request for test plan in prototyping stage.

Lessons learned documented, circulated – OK

Problems and concerns – OK other than all above