LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

	LIGO T970150-00	**-D**	4Aug97
Document Type	*Doc Number*	*Group-Id*	*Date*

LIGO Detector Subsystem Review Report

DESIGN REQUIREMENTS REVIEW
Core Optics Support Subsystem

Title

Review Board: M. Fine, P. Fritschel, F. Raab,
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This is an internal working note of the LIGO Project

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REPORT ON THE DESIGN REQUIREMENTS REVIEW OF THE CORE OPTICS SUPPORT SUBSYSTEM

Signature Page

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REPORT ON THE DESIGN REQUIREMENTS REVIEW OF THE CORE OPTICS SUPPORT SUBSYSTEM

PARTICIPANTS

Presenter

- M. Smith

Review Board

- M. Fine, P. Fritschel, F. Raab, D. Reitze, D. Shoemaker (Chair), R. Weiss

DOCUMENTS PRESENTED AND DISCUSSED

Reviewed Design Requirements (DRD) and Conceptual Design Documents

- Core Optics Support Design Requirements Document, LIGO-T970071-00-D
- Core Optics Support Conceptual Design Document LIGO-T970072-00-D

Viewgraph Handouts

- LIGO-G970067-00-D

REVIEW BOARD REPORT

The review was conducted on 4 April 97, in the CIT SCR/MIT Library. The presenter summarized the design requirements and conceptual design, illustrated by the viewgraph handouts, and the Board discussed the documents, the presentations, and the Requests for Action. The Review Board charge (as specified in document LIGO-L970115) and its response:

1. **Charge:** Determine whether the requirements identified in the Design Requirements Documents are complete; advise whether proposed requirement values are appropriate; if needed, recommend additional requirements to be specified; and recommend other appropriate actions.
   Response: The Core Optics Support Requirements were complete and appropriate except for questions to be resolved through Action Items below. It is possible that the response to some of the Action Items will add to or change the Requirements, but the Review Board believes that they are substantially correct.
2. **Charge:** Evaluate the conceptual design of the Core optics Support subsystem to determine if it is consistent with the DRD, and sufficiently developed to proceed with the Preliminary Design.
   Response: The conceptual design assumed the necessity of trapping weaker beams than may be necessary; simplification of at least many baffles may also render irrelevant some of the action items below.

3. **Charge:** Evaluate the preliminary design phase plans and schedule. Specific points to consider include:
   - are technical risks identified and is the planning responsive to the risks?
   - have interfaces and scope been properly and clearly defined?
   - have technical points of contact been identified?
   - does the preliminary design task and schedule plan identify intermediate milestones?
   - are sufficient resources available to meet the plan?
   - is the preliminary design phase plan consistent with overall LIGO planning?

   Response: These issues need more attention. A review of the preliminary design plans should take place before much time in the preliminary design phase elapses.

General comments

The review was a success, and the establishment of the COS on a solid footing is an important step forward.

RECOMMENDED ACTION ITEMS

SYSTEMS

1. Determine the polarization of light used in the interferometer.
2. Publish an updated plan for the overall Optical Layout task, including a Monte-Carlo calculation and interpretation by experts in that field (e.g., Breault), and coordinated with COS planning.
3. Specific ports used by ASC must be communicated to COS; a naming convention for the ports is also needed.
4. Applications for the mock-ups and a plan for their use should be developed, reviewed, and put into action.
5. Integrate baffles, suspension cages, etc. into the optical layout to determine overall compatibility, ensuring sufficient room for main and optical lever beams. Similarly, check for clearance for pick-off and ghost beam propagation in the more complete model.
6. Revise the ETM transmission called out in the DSR (20 ppm) based on the better IR coating information now available. Revise the ETM output relay system design accordingly.
7. A review of the beams extracted from Core Optics is needed to ensure that each beam has a real use that justifies cost of extraction. For example, it appears that PO RM has no customer, but there is no POBS extracted which may be needed. A table with the extracted beams in one column with the use another column should be put into the DSR.

REQUIREMENTS/INTERFACES

8. COS is responsible for the baffles in Vacuum Manifold; include them in the design. Systems Engineering will supply design information.

9. COS is responsible for the relay optics for the antisymmetric port; include them in the design.
10. Use/develop standard terminology for PO beams (e.g., Dark Port becomes Antisymmetric Port, Reflected Port becomes Symmetric Port).
11. A top-level requirement for the overall transmission of the COS is given in the DSR as 0.99. This should be echoed in the COS DRD and considered in designs (especially Faraday Isolators); variances should be discussed.
12. Beam quality (as gaussian mode amplitudes or Zernikes) for the beam delivered by the COS system should be given as a top level requirement within COS, with internal COS flowdown between the relay mirrors, telescope, window, and any isolation (Faraday etc.). COS should deliver gaussian beam parameters at the output of target design to ASC to allow evaluation of impact on ASC.
13. Ensure consistency of COS design with the interferometer beam sizes and the tolerance for variability given the range of beam parameters anticipated as a function of absorption and input power.
14. An estimate of the optical loss of the empty chambers as optical cavities (black body cavities) should be made. Glints should be included. This will be helpful in deciding how many of the ghost beams need attention.
15. Given the presence of baffling in the beam tube and the net average reflectivity of the Vacuum Equipment, motivate need for COS baffling of GBHRn, GBARn, $n \geq 3$.
16. Give explicit calculations and derive requirements for handling of the bulk scatter generated by the substrates, the very small angle scatter from 2- or 4- km distant mirrors, and the scatter from other in-vacuum hardware (e.g., suspension cages).
17. Clarify the interface between ISC and COS. COS should generate the allowable BRDF for a given pickoff (assuming no Faraday); ISC should determine if this is feasible; if not, further measures (Faraday or other isolation) becomes a requirement. ISC should establish the estimate of BRDF and (seismic and acoustically induced) motion of ISC components.
18. The motion of the SEI optics table was derived at 100 Hz from SEI performance requirements. In fact, the attenuation of the stack does not rise above ~30 Hz. Take the upper limit of calculated thermal noise and assumption of increasing attenuation (continuation of slope) for the 100 Hz number to determine the K value for 100 Hz, and follow up consequences (if any). In this light, consider if the baffles can be attached to the Vacuum Equipment.
19. Document any calculations already performed or other considerations which can be useful in extending the performance of the interferometer to lower frequencies (enabling Advanced Subsystems LIGO design). In particular, the vacuum equipment wall motion may become more important.

CONCEPTUAL DESIGN

20. Use the requirements on bulk scatter etc. to determine the need for the rest (non-black-glass part) of the cone and its performance; consider partial cones, or patches of absorptive material.
21. The use of in-vacuum Faraday isolators has been proposed. Consider alternative attenuation

methods, in conjunction with LSC/ASC (being responsible for the backscatter): Quarter-waveplate/polarizer, Photodiode in vacuum, Output MC, Seismic isolation of components (ISC or a Faraday Isolator) outside the vacuum. Take into consideration beam quality and attenuation in large-aperture Faraday Isolators in the trade, as well as other considerations under study by IOO for their Faraday Isolator application.

22. Consider alternative demagnification telescope designs which do not require off-axis parabolas and which minimize in-vacuum components. One possibility is to fold the telescope using flat mirrors to minimize incident angles, or first-order correction using a cylindrical mirror. Another is to use lenses. Another is to place only one mirror in the vacuum system.
23. Definition of a bolt hole pattern/interface for baffle attachment to the side of the optics table is needed ASAP for SEI 1st article. Define the general attachment arrangement and the interface to SEI (which will in the future be an interface constraint on the COS baffles).
24. Determine the approximate weight of the baffle based upon the conceptual design; can it be supported by the SEI?
25. The mechanical resonances in baffles mounted on the Seismic optics table must be evaluated similarly to the resonances in the suspension cages. Perform a finite element analysis of the proposed conical baffles. Define requirements for 1st resonance, using the Suspension system as a model and for requirements. Consider both thermal motion of baffle leading to scattering noise, and thermal motion of the baffle driving the test mass via the optics table.
26. The main optical system is floating, the COS telescope is mounted to the stack, and the LSC telescope is mounted to the ground. Consider relative motions of the optical axis and the telescopes; can this lead to significant changes in the telescope performance? Consider the PO beam jitter at stack resonances; bothersome for LSC (photodiode uniformity) and ASC (translation into false angular information). Consider drifts in the stack position and angle and its impact on pointing (to ISC).
27. Installation ordering needs attention. Telescopes for POs need to be in place for some initial alignment efforts, but may interfere with alignment beams.