# LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
# - LIGO -

CALIFORNIA INSTITUTE OF TECHNOLOGY
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***LIGO Detector Subsystem Review Report***

## DESIGN REQUIREMENTS REVIEW
## Core Optics Components

*Title*

Review Board: J. Camp, P Fritschel, S. Kawamura, A. Lazzarini,
D. Shoemaker (Chair), R. Spero, R. Weiss, M. Zucker

*Authors(s)*

*This is an internal working note*
*of the LIGO Project*

**California Institute of Technology**
**LIGO Project - MS 51-33**
**Pasadena CA 91125**
Phone (818) 395-2129
Fax (818) 304-9834
E-mail: info@ligo.caltech.edu

**Massachusetts Institute of Technology**
**LIGO Project - MS 20B-145**
**Cambridge, MA 01239**
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

# REPORT ON THE DESIGN REQUIREMENTS REVIEW OF THE CORE OPTICS COMPONENTS

## Signature Page

**Review Board:**

Jordan Camp
J. Camp

Peter Fritschel
P. Fritschel

Seiji Kawamura
S. Kawamura

23.05.96
A. Lazzarini

15 May 96
D. Shoemaker (Chair)

30 MAY 96
R. Spero

Rainer Weiss
R. Weiss

M. E. Zucker 5/24/96
M. Zucker

# REPORT ON THE DESIGN REQUIREMENTS REVIEW OF THE CORE OPTICS COMPONENTS

## PARTICIPANTS

### Presenters

B. Kells, G. Billingsley, D. Jungwirth

### Review Board

J. Camp, P Fritschel (via telephone), S. Kawamura, A. Lazzarini, D. Shoemaker (chair), R. Spero, R. Weiss (via telephone), M. Zucker (via telephone)

### Other attendees

W. Althouse, D. Coyne, S. Elieson, R. Fischer, J. Hazel, S. Whitcomb, H. Yamamoto, W. Young

## DOCUMENTS PRESENTED AND DISCUSSED

### Reviewed Design Requirements (DRD) and Conceptual Design Documents

- "Core Optics Components Requirements (1064 nm)", LIGO-E95099-01D dated 1/29/96
- "Core Optics Components Conceptual Design (1.06 μm)", LIGO-T960016-00D, dated 2/6/96

### Viewgraph Handouts

- Kells COC VGs and Jungwirth Testing VGs (LIGO-G960016-00D)
- Billingsley: COC DRR - Pathfinder VGs (LIGO-G96011-00-D)

## REVIEW BOARD REPORT

The review was conducted on 23 February 1996, in the Caltech LIGO Science Conference Room. The presenters 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-L960085) 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 Components Requirements were complete and appropriate except as noted below. There are many comments which will require attention, but the Committee believes that the Requirements are in a form to allow the design process to proceed.

2. **Charge:** Evaluate the conceptual design of the COC to determine if it is consistent with the DRD, and sufficiently developed to proceed with the Preliminary Design

   **Response:** The conceptual design is appropriate and complete at the current stage of design, except as noted in the Action Items below. We recommend that the COC proceed with the Preliminary Design in parallel, insofar as possible, with the execution of the Action Items.

## RECOMMENDED ACTION ITEMS

## REQUIREMENTS FLOWDOWN

1. Concern: There is a lack of definition of SUS-COC interface.
   Action: Refine and finalize the SUS-COC interface; in particular, clear definition and value for the TM thickness (final decision) as interface between SUS + COC is needed immediately to proceed with preliminary design.
2. Concern: Optical interface between IOO and COC should reflect the change in the gaussian beam input parameters associated with the change to 1064 nm and a curved-curved cavity.
   Action: Update IOO-COC interface.
3. Concern: Uniform nomenclature is needed, between subsystems with interfaces to COC and for internal parts and for interfaces.
   Action: Ensure uniformity of naming between subsystems; check for internal consistency.
4. Concern: Actual optical layout has impact on COC; e.g., wedge angles.
   Action: Develop plan for layout and to put into action; COC needs to be addressed.
5. Concern: Due to its thinness, a small wedge in BS is planned. This may cause problems with ghost beams (insufficient separation of beams at next IFO optic).
   Action:
   - 5.1 Consider (trade) change of IFO polarization (to "p") to reduce intensity of ghost beam.
   - 5.2 The requirement on ghost beam separation should be clearly defined.
6. Concern: Length sensing requirements trade/impact with COC requirements are not explicit in COC requirements, including
   - 6.1 Match of arm cavity storage times coupling to AM/FM noise, signal mixing
   - 6.2 BS splitting ratio, similar coupling mechanisms (present 10% unbalance excessive)
   - 6.3 Reflected light from RM as it affects LSC shot noise.
   - 6.4 Requirements for nominal AR reflectivity (control beams vs. Recycling Cavity losses)
   - 6.5 Lowest resonant mechanical mode of TMs (limiting LSC servo performance
   - 6.6 Total arm cavity loss affecting LSC control stability
   - 6.7 Possible trades between large figure errors and wide-angle scatter

   Action: Flow down requirements explicitly.
7. Concern: Lack of clarity of responsibility for internal mode and pendulum $Q$'s in TM's.
   Action:

7.1 Delete discussion of $Q$ w/ attachments; only $Q$ of coated, polished substrate is COC domain.

7.2 Flow down $Q$ to COC and SUS.

8. Concern: Scattering at mid to high spatial frequencies by the moving beam tube is missing in the DRR.
   Action: Requirement on BT scatter to be developed and flowed down to SYS and thus to COC.
9. Concern: Contamination of the optical surfaces.
   Action: Establish vacuum materials practice, and flowdown requirement on contamination to COC.
10. Concern: Responsibility for cleaning and handling of optics.
    Action: Assign responsibility for cleaning and handling of optics to the appropriate subsystems.
11. Concern: 2 km interferometer performance requirements required.
    Action: SRD requirement to be established; flowdown requirements to detector subsystems.

## INTERNAL COC REQUIREMENTS

12. Concern: Static asymmetric clipping and dynamic transverse motion of BS not yet modeled accurately.
    Action: Modify FFT code to accurately model the BS, and perform analysis to asses effects of clipping/transverse motion.
13. Concern: Effect of partial intrusion of the 1 ppm loss contour at ETM by the safety stop is not estimated.
    Action: Run FFT or develop other model with partial and total intrusion and compare them to verity that the partial intrusion is not problematic.
14. Concern: Birefringence requirements are not stated.
    Action: Obtain existing internal and VIRGO documents; use to develop a requirement.
15. Concern: Model for focussing due to thermal lensing required.
    Action: Perform FFT run with effective radius of curvature related to power absorbed.
16. Concern: Table 4: Low absorption fused silica is specified for the recycling mirror, but not motivated.
    Action: Justify (or modify) absorption requirement for recycling mirror.
17. Concern: Surface requirements should be specified in more complete terms, to help in communicating with vendors, outside groups, and in scaling.
    Action: Quote (one or several of) power spectra upper limits, orthonormal functions (Zernike or Laguerre-Gauss), RMS vs. radius (with more apertures) to make a more complete and versatile optics specification.
18. Concern: High surface electric field is a risk factor for mirror contamination, to be avoided if possible.
    Action: Determine if it is possible to have low electric field at the surface of the coating for the desired coating specifications (transmission); if so, consider adopting it as a requirement

## CONCEPTUAL DESIGN and PLANNING

19. Concern: We do not at present have alternatives to REO for coating the optics.
    Action: Evaluate approaches which reduce risk without excessive cost or schedule impact; select one and implement it. Investigate the possibility that LIGO may use the VIRGO source as a back-up for coating. Zeiss should also be queried.
20. Concern: The logical flow of certifiability during the LIGO procurement phase is not explicitly laid out, and appears to depend on equipment not yet built.
    Action: A explicit plan of the logical flow and the fall-back options for certification/metrology of the polished substrates to be developed.
21. Concern: A procurement plan is needed soon, given the desire to move quickly.
    Action: Give development of a procurement plan high priority.
22. Concern: There is a continuing concern about anisotropy of the homogeneity of BS substrate material.
    Action: Survey Industry/VIRGO experience/LLNL experience, etc. to determine the present understanding of the anisotropy of BS materials (VIRGO is presently making homogeneity measurements of a beamsplitter). Take action as needed to resolve the issue.
23. Concern: Any perpendicular surfaces between surface 1 or 2 and the side (cylindrical wall) of the optic leads to a "glint" that reflects part of the beam directly back along the optical axis (like a dihedral).
    Action:
    - 23.1 Ensure that the probability of 'glints' is minimized, by avoiding right angles in the substrate design. Check the resulting design with ray-tracing.
    - 23.2 Review the design for interface compatibility; communicate design to SUS.
24. Concern: The bevel width infringes on both COC and SUS design flexibility.
    Action: Minimize the width of the bevel; contact industry to find minimum allowable; ensure uniformity (given the wedges).
25. Concern: There will be clipping of the beam by the suspension sensor/actuator on BS.
    Action: Explore design modifications limiting interference; for example, moving magnets closer to edge of optic, and/or moving OSEMS away from 45 degree points on BS to reduce optical clipping.

## DOCUMENTATION

26. Action: Number of different kinds (diameters, curvatures, thicknesses) of optics unclear. Make table of number and kinds of optics, number of spares.
27. Action: There is confusion about the BS orientation (50/50 side or AR side towards the Recycling mirror) from the nomenclature; define terminology and clarify description.
28. Action: Indicate the reason for the use of a cylindrical optics form (the practical shape with highest modal frequencies for a given mass).
29. Action: Briefly summarize the choice of fused quartz as a substrate material (low loss, low birefringence, high homogeneity, high mechanical Q, high transmission, experience in polishing).

30. Action: Table 2: Parameters of 4000m COC. Useful to have lowest flexural mode and longitudinal mode separation listing.
31. Action: Table 8 should be extended down to 10 ppm to help understand scaling.
32. Action: Confusion over surface flatness description, due to different reference wavelengths. All measurements to be given in nm, not $\lambda$.
33. Action: Requirements and specifications are not well separated in the documents. Ideally, only requirements should be in DRD. Specifications should be in Conceptual Design Document. Address when/where possible.