LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -

CALIFORNIA INSTITUTE OF TECHNOLOGY
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LIGO Detector Subsystem Review Report

PRELIMINARY DESIGN REVIEW
Prestabilized Laser (PSL)

Title

Review Board: A. Abramovici, W. Althouse (Chairman), A. Lazzarini, V. Schmidt, R. Spero, S. Whitcomb, M. Zucker

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This is an internal working note
of the LIGO Project

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REPORT ON THE PRELIMINARY DESIGN REVIEW OF THE PRESTABILIZED LASER (PSL)

Signature Page

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Accepted by:

R. Vogt
Detector Group Leader

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REPORT ON THE PRELIMINARY DESIGN REVIEW OF THE PRESTABILIZED LASER (PSL)

PARTICIPANTS

Presenter

J. Camp.

Review Board

A. Abramovici, W. Althouse (Chairman), A. Lazzarini, V. Schmidt, R. Spero, S. Whitcomb, M. Zucker (via telephone).

Other attendees

K. Blackburn, J. Heefner, D. Jungwirth, G. Sanders, N. Solomonson, R. Vogt.

DOCUMENTS PRESENTED AND DISCUSSED

Reviewed Documents

Design Requirements Document (DRD): *Prestabilized Laser Design Requirements,* J. Camp, LIGO-T950030-03-D, May 25, 1995.

DRR report: *Design Requirements Review -- PSL and PSL Controls* (Subsystem Review Report) LIGO-E950005-A-D, March 16, 1995.

Memo from J. Camp regarding disposition of action items from the PSL DRR, LIGO-L950337.

PSL Preliminary Design Review, Viewgraph Handouts

REVIEW BOARD REPORT

The review was conducted on June 6, 1995, in the LIGO Engineering Conference Room. The presenter summarized the outstanding Action Items from the PSL Design Requirements Review, the PSL Design Requirements, the current state of the PSL design, and the PSL prototype test program (see copy of Viewgraph Handouts). The Board reviewed these materials, including a page-by-page review of the revised Design Requirements Document (DRD). The Review Board charge (as specified in document LIGO-L950413) and its response:

1. **Charge:** Determine whether the action items from the February 6, 1995 Design Requirements Review (DRR) have been completed and incorporated, as needed, in the Design Requirements Document in its final form.

   Response: The Board notes that of the 26 Action Items assigned at the DRR, all but approximately 8 were incorporated in the revised PSL DRR. The unresolved Actions were thoroughly discussed at the Preliminary Design Review (PDR), and those that were not closed

appear (in revised form) in this Report. The Board anticipates that with these revisions (and with changes to format for the purpose of standardization), the DRD will reach a satisfactory final form.

2. **Charge:** Determine that all design issues have been resolved, allowing the initiation of the Final Design Phase of the IFO part of the PSL subsystem

   Response: Several design issues remain unresolved, but none of them are likely to influence the initial stages of the Final Design activity. The Board therefore does not recommend delaying the Final Design, but encourages expedient closure on these issues early in this phase.

3. **Charge:** Determine the adequacy of the Test Plan for the ongoing PSL prototype test activity.

   Response: The test plan as described was approved by the Board, except for technical additions noted in the Action Items, and the recommendation for expanded documentation.

RECOMMENDED ACTION ITEMS

Design Requirements and Flowdown

1. Eliminate references to the PSL prototype performance in the statement of design requirements; requirements should flow down from System Integration level considerations. In particular, the required power level should be determined by the overall detector shot-noise limited sensitivity.
2. Reconsider the proposed 95% availability for the PSL, in light of an availability analysis of all subsystems and the required overall availability of 90% (95% for the PSL may be too low). Include all sources of downtime in PSL availability estimate, such as ringdown measurements and laser gas fills.
3. Evaluate required PSL output power with explicit accounting for all losses, including losses in IOO (losses may be higher than estimated).
4. Provide a model for and calculate the common mode rejection of frequency noise in the interferometer arms.
5. Provide a definitive calculation of the reduction in intensity noise provided by the recycling cavity. This is urgently needed, as an intensity stabilization system of much higher gain than assumed may be required.
6. Include safety margins on required beam jitter and intensity noise.

Design Requirements Document

7. Perform a safety hazard analysis of the PSL.
8. Summarize the changes in content of the DRD since the version reviewed at the DRR. Provide reasons for changes.
9. The DRD lacks a technical description of all preliminary design features. Without more technical details (including additional text, diagrams, and listing of critical components such as the fast laser PZT), the design cannot be certified to contain all essential details. The design

documents should progress from "Conceptual Design" to "Preliminary Design" to "Final Design." The current state of design documentation does not include the level of detail required of a Preliminary Design.

10. The PSL Definition (Section 3) should include a structured naming convention, and a corresponding block diagram.
11. Figure 3 is inadequately labelled and incomplete: the photodiode needed for the Power Stabilizer servo is not shown, and the Faraday Isolators and Pockels Cells may be improperly located. The labels should correspond to a standard naming convention for components and signals. Use standard symbols for optical and electronic components.
12. Where appropriate, refer to the CDS DRD.
13. Change noise specifications from "less than" to "less than or equal."
14. Eliminate the Appendix, in favor of a Requirements Flowdown.
15. Use SI units throughout.
16. Number all equations.
17. Safety should be removed from the interfaces section, and elevated to the top level. The section on safety should reference relevant standards (such as ANSI), and include water leak detection, redundant systems to safeguard against eye injury from laser beams, and lockout systems.

Conceptual Design, and Implementation

18. Reconsider the assumed 4000 hour plasma tube MTBF, in light of manufacturer's estimate of 2000 hours; consider implementing a monitoring scheme to anticipate plasma tube failure.
19. Determine if a control system is necessary for pointing of beams on the optical tables; if needed, it should be designed and tested early.
20. Reassess the proposed backup laser scheme for reliability, and consider designing a backup system that includes completely redundant PSL optics and electronics.
21. Include in the backup system signal descriptions needed for CDS design (for example, off-line testing may require a low-pass filter to simulate the optical response of the mode cleaner).
22. Analyze the requirements for optical isolation from the interferometer, and assign isolation requirements to subsystems (PSL, IOO, LSC); evaluate whether the PSL needs one or more Faraday Isolators.
23. Consider adding wavefront sensing for alignment of the reference cavity.
24. Determine whether the Spectra Physics laser has adequate tuning range for reliable lock to a 1 m reference cavity; if necessary, consider increasing the length of the reference cavity or adding piezo-driven length control for lock acquisition.
25. Select a g-factor for the reference cavity that provides a good compromise of alignment stability and rejection of spurious modes.
26. Reconsider the optimum placement of the laser power supply, in light of increased electrical radiation as the power umbilical length is increased.

27. Include incandescent lights to illuminate the rf photodiode, controllable by CDS, to allow for tests of shot noise sensitivity.
28. The kinematic mounts proposed for the laser tables seem unnecessary, and should be eliminated from the design in the absence of established need.

Test Plan

29. The test plan should be more complete and specific. It should be expanded to include details such as sampling rates for drift and transient capture, and optical efficiency measurements. There should be provision for measuring fast power transients, and transients in PZT voltages.
30. Include measurements of loop gain, gain/phase margins, actuator crossovers, and dynamic reserves.
31. The tests listed in DRD Section 8.1.1 as scheduled for the beginning and the end of the test period should also be conducted after 1 week, 2 weeks, 4 weeks, and 8 weeks.
32. The prototype test plan configuration should be the same as that of the PSL design (for example, the testing should not use fiber optics to couple into the reference cavity).
33. The Availability tests should include recording of laser gas fills, lab temperature, and reference cavity temperature.
34. Include monitoring of signals that may be useful for failure prediction.

Interface Considerations

35. Include in the optical interface the beam waist size, location, and asymmetry.
36. Specify the footprint of PSL equipment, as interface to Vacuum Equipment/Facilities.
37. Include interfaces with the vacuum equipment, such as shared pumping facilities for initial pumpdown of reference cavity, and maintenance needs of pumping equipment.
38. Include in the technical description vacuum elements and any temperature control of the reference cavity, and any CDS interfaces for the clean air/HEPA system.
39. Include, if needed, video cameras in the vicinity of the PSL optical tables; specify which subsystem is responsible for the cameras, transmission cables, and monitors.
40. Include inputs for two input signals in the PSL electronics design: one from the input mode cleaner (IOO Subsystem), and one from the full-length interferometer (LSC Subsystem).
41. Specify the ringdown measurement parameters and required accuracy for all relevant cavities.

Other Recommendations

42. The meaning of the signature page, to be signed by interfacing Subsystem Managers, should be clarified.