G950095-00-D

ASC Optlev DRR

Optical Lever Design Requirements Review

14 November 95

David Shoemaker, John Tappan

Review Board

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ASC Optlev

Design Requirements Review

AGENDA

Charge and Introduction (WEA)

Optlev System Requirements and Interfaces (1 hour, DHS)

- Overall structure of DRR, task
- Scope
- Top-level Requirements
- Significant design drivers, impact on other systems
- Interfaces

Conceptual design of Optlev (30 min, John Tappan)

- Components
- Specification drivers
- Concerns

CDS Optlev DRR (30 min, Jay Heefner)

Optlev Test Plan (30 min, DHS/JHT)

- Objectives
- Outline of Plan

Discussion of ASC Design Requirements Document (1 hour)

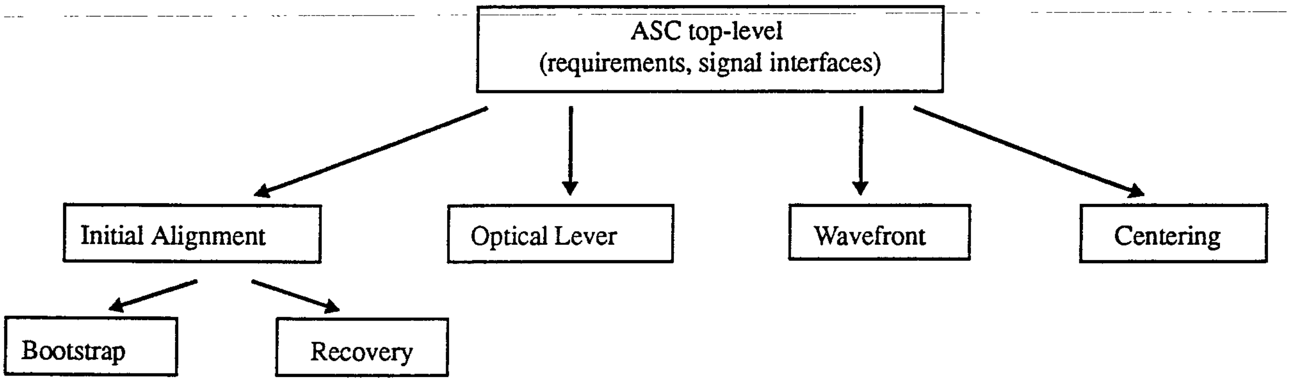
Overall structure of ASC task

ASC System Level

- Coordination between ASC subsystems

ASC Subsystems

- Initial alignment (get the beam down the tubes)
- **Optical levers (hold an alignment for a little while)**
- Wavefront sensing (determine the ideal alignment)
- Centering (determine the right spot on the mirrors)



Optlev Scope

All short-term angular measurement and control,

for all suspended components of the Detector

- test masses
- beamsplitter and recycling mirror
- input and output optics
  - Mode Cleaner
  - matching telescope(s)
  - steering mirrors

Role in interferometer start-up:

- to hold a predetermined alignment while attempting to lock ifo
- leads to requirements for ‘long term operation’
- presently, no requirement for >10 minutes, or through pumpdown

Role in interferometer operation:

- to hold operational alignment for times shorter than several seconds
- leads to requirements for GW band noise feedthrough
- precision alignment derived from Wavefront sensors

Optical Lever

Roles of local precision angular control

- damping of angular mirror resonances before alignment
  - suspension's sensors and actuators ideal---large dynamic range
- aid in initial alignment--beams down tubes; finding acquisition alignment
  - suspension's sensors and actuators---adequate;
  - stability limited by stack drift and resonances
  - ultimately slab-slab motion (see below)
- closed-loop control of mirrors during operation (with Wavefront input)
  - NOT suspension's sensors and actuators!
  - signal-to-noise of suspension's sensors insufficient
  - Optical Levers with paths of ~5-50 meters serve this role

Requirements and Environmental input 'in-between' solutions

- microseismic tilt is about 4×10^{-8} rad, 7 second period; biggest effect
  - assuming tilt scales with translation, ok Hanford value
  - do not know for Livingston; probably within factor 2
- end mirror operational alignment tolerance 2×10^{-7} rad summed
  - each could be 1/2 this, if no other misalignment in ifo
  - acquisition angle only estimated to date
  - at least 3 time operational, or back mirrors 6×10^{-7} rad summed

No 4 km lever arm sensing proposed

- alignment to be maintained slab-slab by wavefront sensor

Optical Levers (con't)

Arguments for Optlev closed-loop operational control

- keeps the bandwidth of the wavefront sensor below time constants
  - no dynamic analysis of Wavefront control system needed
  - reduced risk of length-angle coupling
- Allows extensive filtering/interpretation of Wavefront information
  - gives insurance against signal/noise problems, higher modes...
- allows short-term diagnostic operation without wavefront sensor
- familiar from 40m operation

Arguments against Optlevs

- very complicated optical layout problem for initial interferometers
- gives second coordinate system, no intrinsic connection to ifo.
- design and prototyping and production and installation: $ and time
- familiar from 40m operation

Present baseline carries Optical levers, operational control.

System Noise, 10 Hz - 10 kHz

Value:

<1/10 the greater of seismic noise and suspension controller noise

- require that the OptLev not degrade the performance of the interferometer during operation at all GW frequencies
- thus, must not significantly increase the motion of the test mass
    - › in rotation (expected effect)
    - › in translation (due to unbalances in drive coils)

Coupling mechanism:

- angle sensing system noise
    - › 'fundamental' (shot noise in quadrant photodetector)
    - › technical (excess noise in light source)
- servo loop forward gain in GW band
    - › expected Unity Gain Frequency of order 1-10 Hz
    - › sharp filter to cut signal above UGF

Context

- system must perform somewhat (10x) better than Susp Sensors
- more light, longer lever arms assures this

System Noise, 0.002-10 Hz

Value:

$<10^{-8}$ rad RMS angular motion over this bandwidth in each of θ and ϕ

- require that the Optlev hold operational alignment for several minutes
- requirement of 10^{-8} rad comes from Modal Model of complete ifo
  - believe that locking should work out to 10^{-7} rad
- requirement of 0.002 Hz (500 Sec, 9 minutes) from operation scenario
  - long enough to verify an initial alignment, attempt locking
  - long enough to run diagnostics on ifo without Wavefront sensor
- foundation stability crucial to performance of Optlev
  - determines reference for any solution tied to slab

Baseline

Value:

from 5 m to 50 m

- require that the Optlev perform to Noise Requirements over
    - shortest baseline (mid- and end-stations allow ~5.5 m)
    - longest baseline (full length of Vacuum manifold <50m)
- significant impact from foundation stability for both baselines
    - not clear that longer baselines help significantly
    - only partial understanding of foundation; learning more
- long baseline leads to specifications for optics size, collimator flexibility

Dynamic Range

Value: to be greater than 10^{-4} rad

- require that the initial dead-reckoning Optlev alignment include the correct angle for 4km pointing
- this allows setup/alignment of the Optlev without iteration
- monuments to be installed with best GPS (<3mm) precision
  - over 50m baseline, gives 6×10^{-5} rad possible error
  - over 5m baseline, gives 6×10^{-4} rad possible error, BUT
  - for given sensor size, dynamic range is then 10^{-3} rad
- thus, requirement is poorly stated: should be

Dynamic range to be sufficient to dead-reckon Optlev alignment.

Beam Size

Value: less than 1 cm $1/e^2$ diameter

- require that the Optlev not use excessive beam tube section
- will use TEM_{00} beam, and minimum size for required baseline
- requirement is 'reverse-engineered' for practical wavelengths
- not difficult to meet.

Interfaces within Detector

Mechanical Interfaces

- shelves/slots in CDS Equipment rack (CDS)
    - diode laser power supply
    - CDS equipment
- steering mirror support (SEI)
    - in vacuum
    - scariest interface
- cables (CDS)
    - optical fiber

Interfaces within Detector

Electrical Interfaces

- angular control signals (IOO, COC)
    - › sent via CDS
- offsets to summing junctions (ASC Wavefront)
    - › internal to ASC, via CDS (hard-wired?)
- sensor/actuator signals for diagnostics/monitor (CDS)
    - › Meas, Ref position detector currents
    - › laser intensity monitor
    - › tilting mirror driver control signals
    - › intensity controller control signals
- gain, offset adjusts for servoloops
    - › laser diode intensity
    - › Optlev beam pointing
    - › Sensed optic pointing

Optical Interfaces

- Optlev beams on Sensed Optic
- no direct interface with GW-sensing beam
- viewports belong to Optlev (mechanical interface with VacEq)

Stay-clear zones

- Optlev beam clearance around detector components
    - › 1 cm diameter minimum; target 3 cm to minimize scatter

Interfaces External to Detector

Mechanical interfaces

- base of equipment rack (CDS?)
- base of equipment support structures (FAC)
- viewports to vacuum chambers (VacEq)

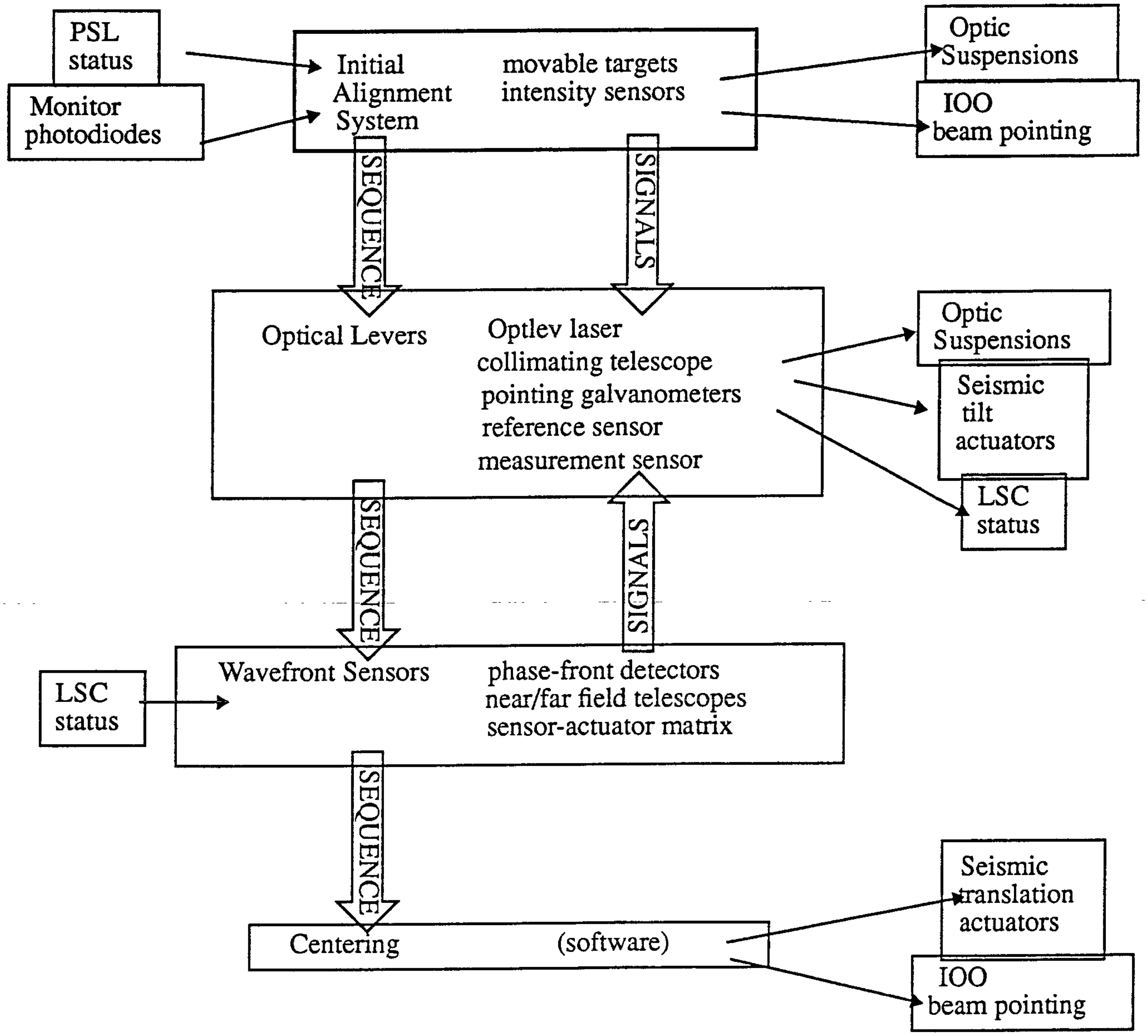
Electrical interfaces

- none

Stay-Clear zones

- space for equipment support structures (FAC)
  - conceptual (immature) notion
  - 1 m^2 surfaces on foundation near each chamber
- optical paths in vacuum system (VacEq)
  - necking on viewport flanges
  - internal or external bracing limiting viewport aperture

Sequences



PSL status

Monitor photodiodes

Initial Alignment System

movable targets
intensity sensors

Optic Suspensions

IOO beam pointing

SEQUENCE

SIGNALS

Optical Levers

Optlev laser
collimating telescope
pointing galvanometers
reference sensor
measurement sensor

Optic Suspensions

Seismic tilt actuators

LSC status

SEQUENCE

SIGNALS

LSC status

Wavefront Sensors

phase-front detectors
near/far field telescopes
sensor-actuator matrix

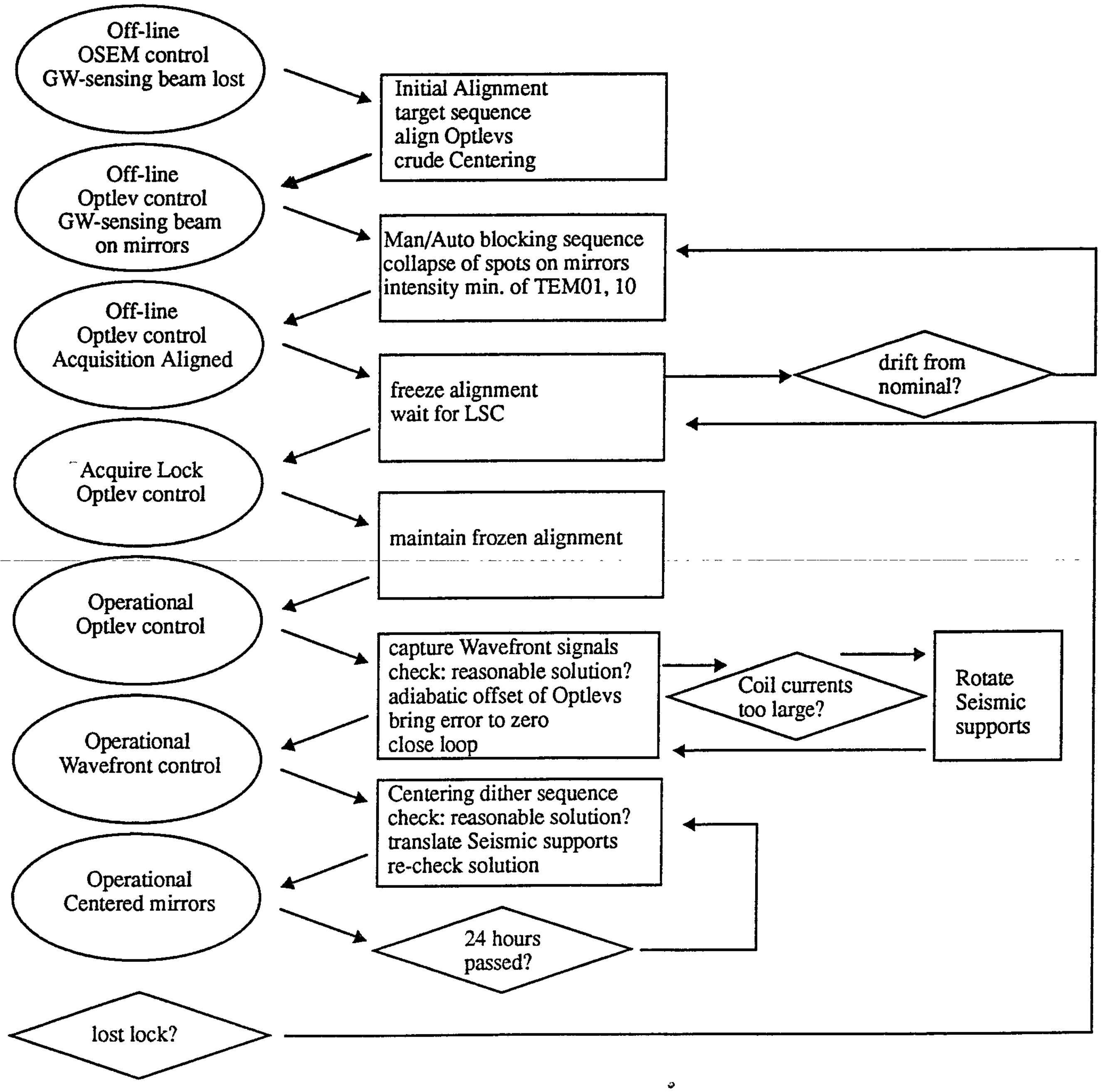
SEQUENCE

Centering (software)

Seismic translation actuators

IOO beam pointing

States



Off-line
OSEM control
GW-sensing beam lost

Initial Alignment
target sequence
align Optlevs
crude Centering

Off-line
Optlev control
GW-sensing beam
on mirrors

Man/Auto blocking sequence
collapse of spots on mirrors
intensity min. of TEM01, 10

Off-line
Optlev control
Acquisition Aligned

freeze alignment
wait for LSC

drift from
nominal?

Acquire Lock
Optlev control

maintain frozen alignment

Operational
Optlev control

capture Wavefront signals
check: reasonable solution?
adiabatic offset of Optlevs
bring error to zero
close loop

Coil currents
too large?

Rotate
Seismic
supports

Operational
Wavefront control

Centering dither sequence
check: reasonable solution?
translate Seismic supports
re-check solution

Operational
Centered mirrors

24 hours
passed?

lost lock?

Environmental input

Seismically/mechanically driven motions:

Gravity-wave band (30→3kHz)

- centering (trivial)
- beam jitter (also of pointing lasers)

Active control band (0.1 →10 Hz)

- damping gain required
- transfer functions for servo loops
- stability of foundation (optical levers)
- relative motion foundation to foundation

Drift/shift regime (*f* < 0.1 Hz)

- tides, weather (daily dynamic range)
- pumpdowns (recovery dynamic range)
- stack drift (yearly dynamic range)

Environmental input (con't)

Microseismic peak

- wide peak in region about 0.1-0.14 Hz
- driven by ocean waves and seismicity; many point-like sources
- results in vertical and horizontal displacements
- also angles
- speed 3-4 km/sec, wavelength typ. 23 km

Center-to-end station motions

- full amplitude is about 5×10^{-8} rad pk (site similar to Hanford)
- LIGO samples this almost fully (4 km instead of 5.75 km $\lambda/4$)
- so expect around 4×10^{-8} rad pk-pk from these corks-on-waves
- right in the middle between operational and acquisition alignment

Implementation

Status and rough schedule

- DRR 14 November (today!)
- order some critical/long lead items (e.g., laser) for test
- late January for PDR
    - like a FDR for prototype effort
- detailed design
- order
- assembly of Optlev, test fixtures
- test and design iteration
- FDR planned for Sept 96

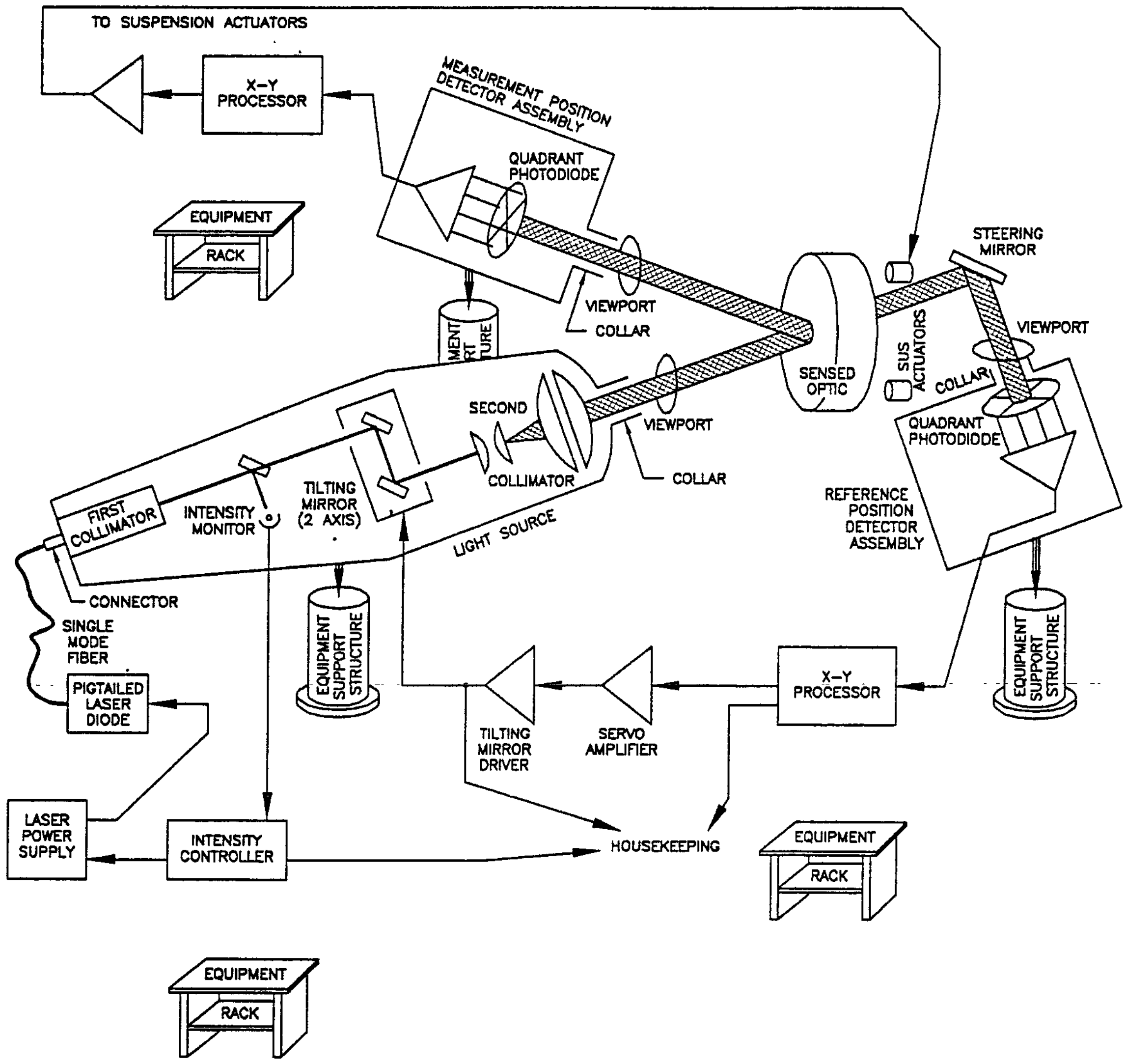
ASC Optical Lever Design
Requirements Review

Optlev Conceptual Design

14 NOV 95

John H. Tappan

Optlev Conceptual Design

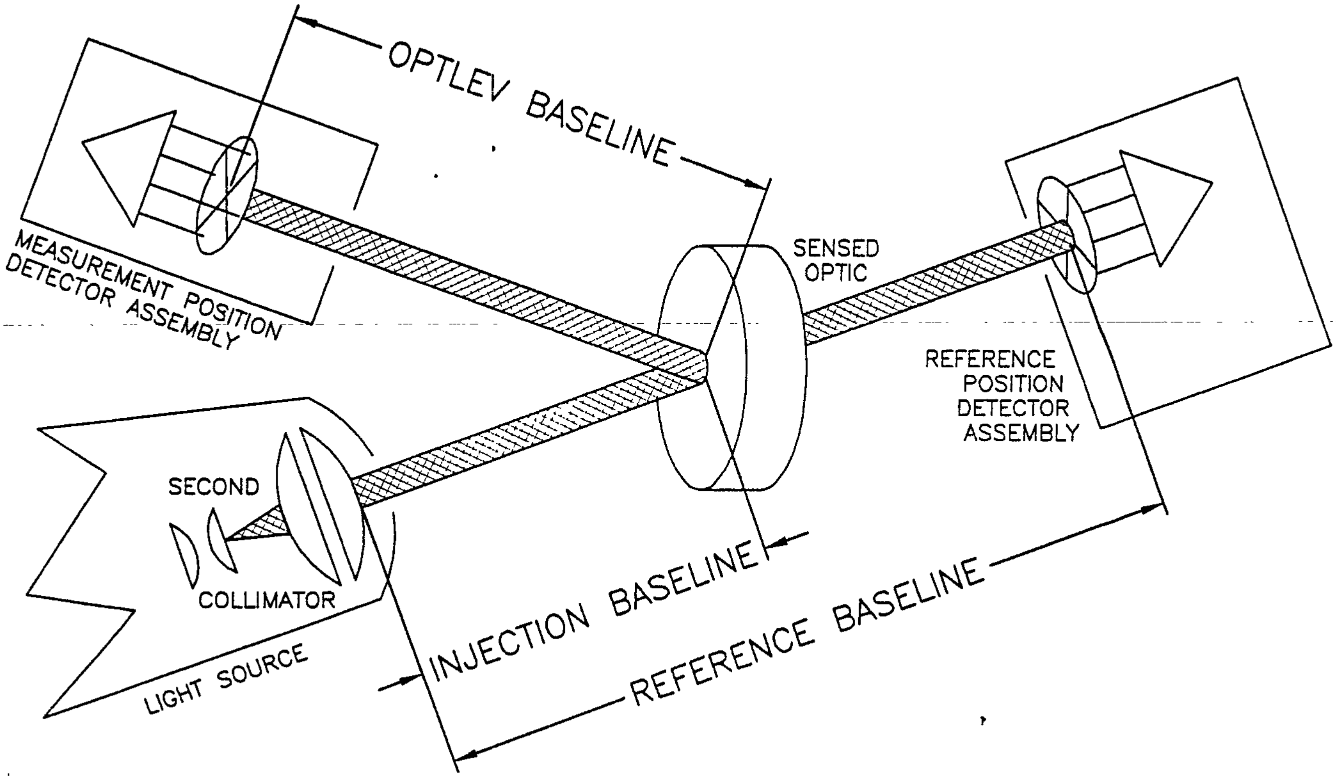


Simplified Schematic of an Optical Lever

Baseline Definitions

Three baseline distances have been identified.

- Optlev Baseline
- Reference Baseline
- Injection Baseline



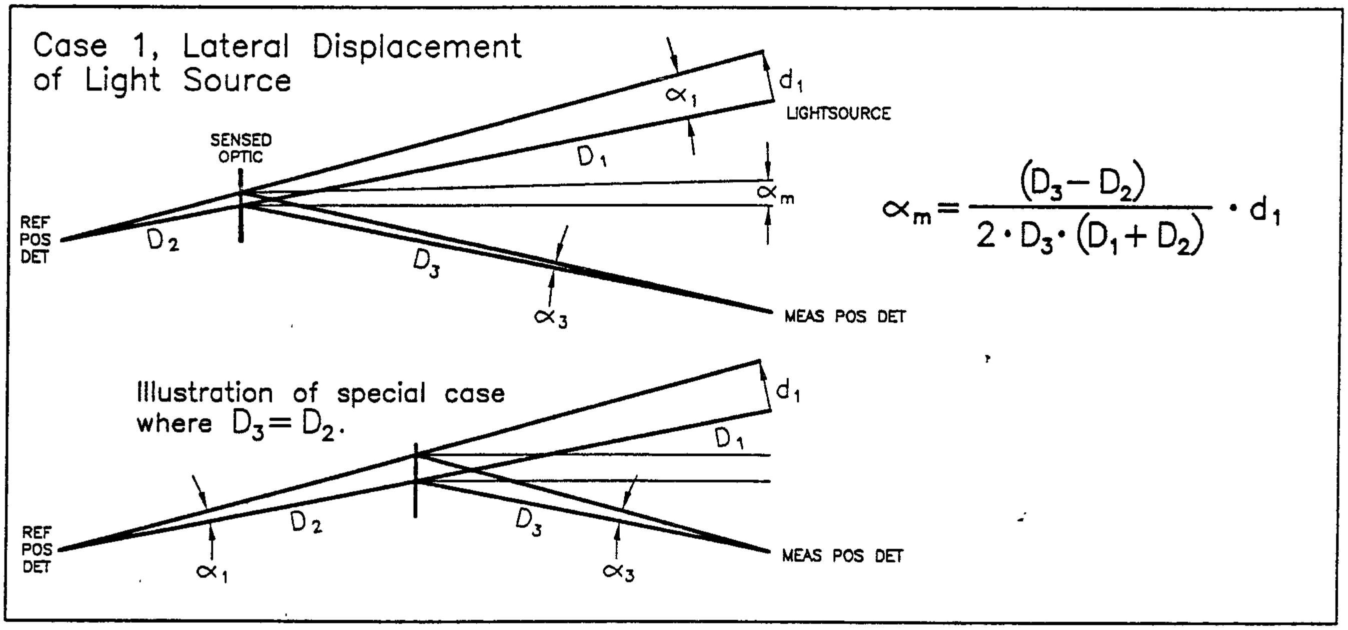
Optlev Baseline Identification

Sensitivity to Component Displacement

Analysis Method

- Simplified V layout without steering mirrors.
    - Perfect (no drift or seismic motion) steering mirrors can be ignored.
    - Injection Baseline = D_1
    - Reference Baseline = $D_1 + D_2$
    - Optlev Baseline = D_3
- Displace one component at a time, except in Case 4, where the Light Source and the Meas Pos Det are considered to be on a common support.
- Determine optic rotation due to that displacement.

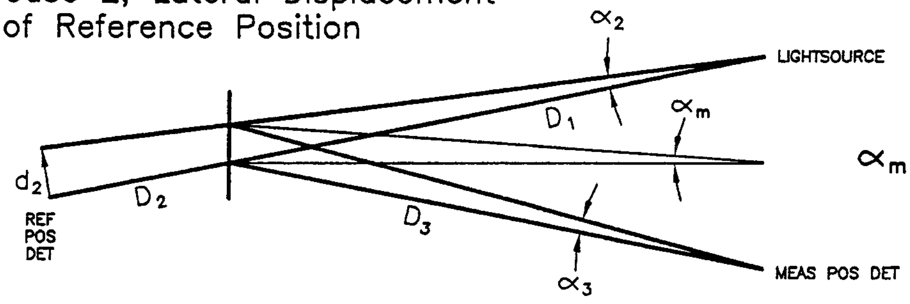
Analysis Results



$$\alpha_m = \frac{(D_3 - D_2)}{2 \cdot D_3 \cdot (D_1 + D_2)} \cdot d_1$$

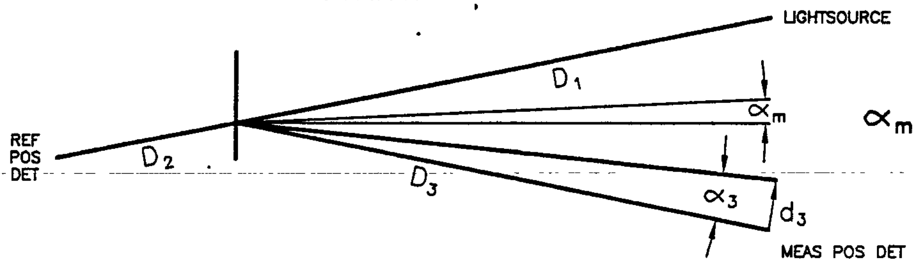
Sensitivity to Displacement (cont.)

Case 2, Lateral Displacement of Reference Position



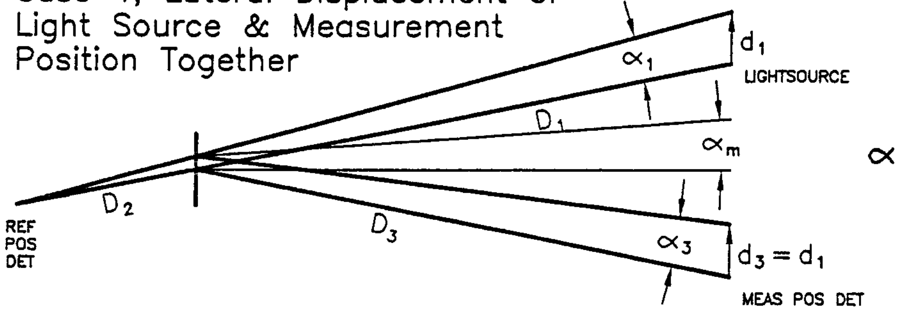
$$\alpha_m = \frac{-(D_1 + D_3)}{2 \cdot D_3 \cdot (D_1 + D_2)} \cdot d_2$$

Case 3, Lateral Displacement of Measurement Position



$$\alpha_m = \frac{1}{2 \cdot D_3} \cdot d_3$$

Case 4, Lateral Displacement of Light Source & Measurement Position Together



$$\alpha_m = \frac{(D_1 + D_3)}{2 \cdot D_3 \cdot (D_1 + D_2)} \cdot d_1$$

Displacement Sensitivity Conclusions

General Rules that follow from the geometry.

1. Maximize D_3, the distance from the Sensed Optic to the Meas Pos Det.
2. Maximize D_2, the distance from the Sensed Optic to the Ref Pos Det.
3. Determine D_1, the distance from the Light Source to the Sensed Optic by the following:
   - If $D_2 < D_3$ then maximize the length of D_1 (most probable case)
   - If $D_2 > D_3$ then minimize the length of D_1.
   - If $D_2 = D_3$ then the length of D_1, has no effect.

Common Equipment Support Structure for Source and Meas Pos Det

- Compare mirror rotation for Case 4 with rotations for Case 1 and Case 3 occuring independently. Assume the amplitudes are the same.
  - The combined effect of Case 1 and Case 3 will only be the same as Case 4 if the displacements, d_1 and d_3, are in phase.
  - There may be some advantage from the size/mass/stiffness of the common Equipment Support Structure, but it would be from the mechanics, not the geometry.

Real World Considerations

Foundation Stability

Steering Mirror Stability

Beam Jitter

Suspended Optic Reflectance

Optlev - Sensed Optic Servo Gain

Foundation Stability

Thermal Distortion

- From air temperature changes inside the building
  - Only calculation from Parsons to date
  - 2F change over 1 hour as input (3×10^{-4}°C/sec)
  - distortions evaluated after 10 minutes of input
  - narrowest slab shows largest distortions
  - for 2 m separation, see 120 nrad, or ~4x operational alignment
  - if linear, give 2.5 mins operational alignment (2×10^{-10} rad/sec)
- Solar heat load
  - asymmetric ensolation probably biggest problem
  - internal heating suppressed by temperature control system
  - question of controller bandwidth, deadbands
  - NOT in favor of pneumatic systems: precision adjustment, etc.
  - external forces on slab not evaluated; not a job for Parsons
  - internal LIGO calculation?

Distortion Due to Mechanical Loads

- Vacuum Equipment loading
  - barometric changes (10%) with 48,000 lb atmospheric pressure
  - partial evacuation (not operational question, but Optlev alignment)
  - to be evaluated by Parsons in coming weeks

Steering Mirror Stability

Steering mirrors a necessity

- no clear paths for V-beams from viewport to viewport
- minimal use as dictated by detailed layout (to be done)

Considerations

- stack drift
  - > worst case 10^{-9} rad/sec, probably 1/10 this
  - > similar to foundation stability
- stack resonances amplifying seismic motion
  - > 3-->15 Hz, Q of 3-10
- not a drift issue, but dragging of mirror due to residual angular servo gain

Solution

- use of in-vacuum quadrant splitter (pyramid)
  - > eliminates first order sensitivity to rotations of stack
  - > keeps first-order sensitivity to translations (stack tilt)
- effect on sensitivity analysis to be done
- to be employed where it can help

Beam Jitter

At > ~100 Hz

- Measurements show beam jitter on exit from single mode fibers to have an upper limit ~10^{-12}m/(Hz)$^{(1/2)}$ and ~10^{-12}rad/(Hz)$^{(1/2)}$. (ref. DHS)

At .002 Hz to ~100 Hz

- Little experience in this frequency range.
  - no likely contributors 1-100 Hz
  - drift from thermal deformations <1 Hz probable
- Sources downstream from the fiber are expected to be large.
  - Monument position drift.
  - Thermal gradients in collimators.

Solution

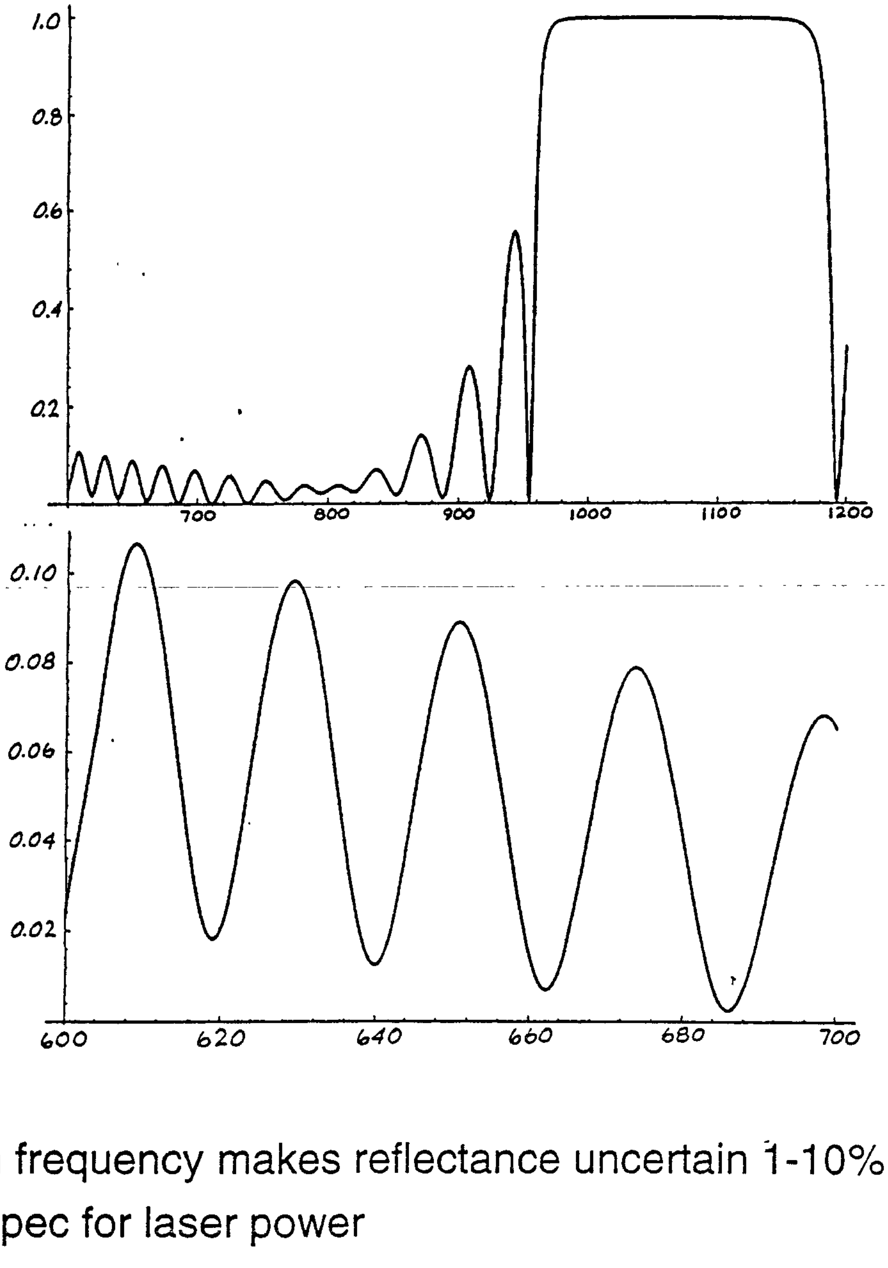
- Servo feedback loop will maintain beam position to the point where angle drift is completely dominated by motion of source and detectors.
  - possible ~100 Hz unity gain frequency
- may tailor servo gain to avoid particular noise terms (stack resonances?)

Suspended Optic Reflectance

Requirements

- calculation shows need for ~0.1 mW on photodetectors

Reflectance
of HR
Coating



Conclusions

- variation with frequency makes reflectance uncertain 1-10%
- establishes spec for laser power

Servo Gain

Input to be suppressed

- NOT long term (~>3 sec) drifts---taken care of by Wavefront Sensor
- seismic input above ~0.3 Hz
    - > insignificant ($<3\times10^{-8}$ rad) if no amplifying resonances
- control of Q of pendulum (role of active damping)
- control of stack resonances (3-15 Hz, low Q already)
- wind-excited motion
    - > 2.54 Hz sway mode
    - > new information from Parsons, needs consideration

Other considerations

- must not induce motion at GW frequencies (well above control band)
    - > constraint on sensor noise and servo gain rolloff rate
- holds alignment before lock is achieved (driver for 10 minute stability)

Plan 1-10 Hz Unity Gain Frequency

- to be refined as noise models are refined
- hardware is flexible, not near any hard technology limits

Hardware

Diode Laser

- Commercially available with TEC and a length of single mode polarization preserving fiber ***inside*** the housing.
  - > Relatively rugged package - no delicate external fiber pigtail.

Fiber Optic Jumper

- Purchased from commercial source in various lengths as needed.
  - > Commercial connector style: TBD

Collimators

- First Collimator probably commercial. The laser diode assembly venders make collimating optics for their packages. The differences between the catalog item and our needs are the optical fiber connection method and, maybe, the stability.
- Second Collimator, TBD

Intensity Monitor Beam Splitter

- Commercial Optic
- Depends on physical layout of Light Source.

Mirror Tilter

- Probably a custom design, though not necessarily.
- Commercial units are not specified at the position resolution needed only because of the limitations of the built-in position sensors.

Hardware (cont.)

Position Detectors

- CDS, based on experience

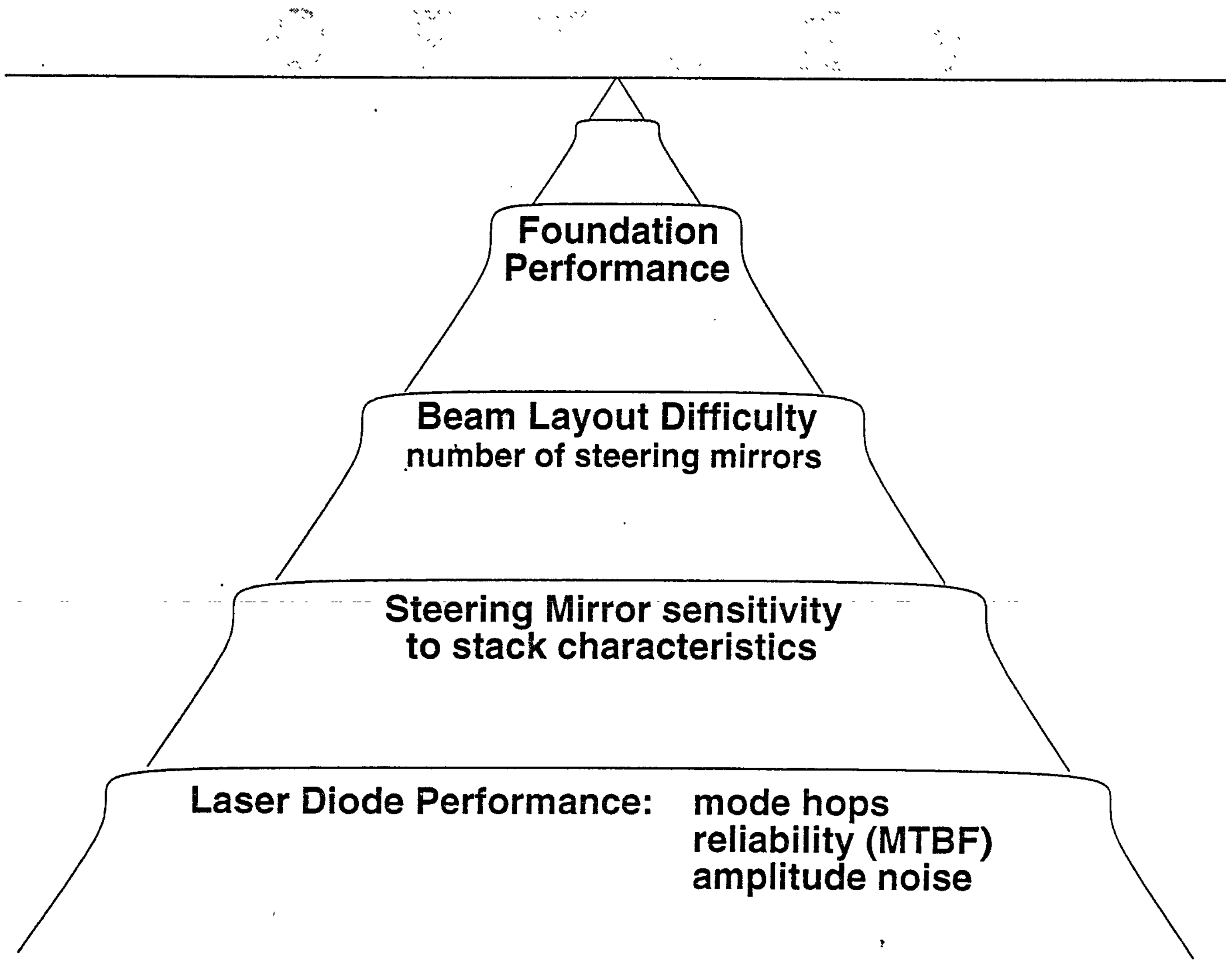
Equipment Support Structures

- Custom design due to thermal stability and interface/stay clear requirements.

Optical Path Sample Layout

Doug Jungwirth

Conceptual Design Speed Bumps



Foundation Performance

Beam Layout Difficulty
number of steering mirrors

Steering Mirror sensitivity to stack characteristics

Laser Diode Performance:
- mode hops
- reliability (MTBF)
- amplitude noise

Optlev Prototype Test Plan

Objectives

- to construct a prototype using components planned for LIGO
- to test all aspects of the Optlev where analysis is not possible
- to iterate the Optlev design to optimize performance, cost

Overall plan

- procure and test individually critical elements of the Optlev
  - refine design, component selection
- build complete Optlev prototype
  - all optics, but with fixed 'sensed optic'
  - all electronics, including EPICS interface
  - mechanical test setup appropriate for measurements
- test on minimum baseline to requirements
  - critical test: angular beam drift and jitter
  - may see required performance over short baseline in air
  - may require ~5m evacuated path

Critical component characterizations

- Diode Laser/fiber optic coupler
  - power, reproducibility with disconnect/connect
  - long term intensity stability, mode hops
  - short term intensity noise
  - frequency drift and jitter
  - mechanical and acoustic sensitivity (intensity modulation)
- first and second collimators
  - beam diameter, adjustment at Ref and Meas Pos Det positions
  - beam 'tails', deviation from gaussian
  - thermal stability
- tilting mirror (beam angle actuator)
  - dynamic range, sensitivity
  - frequency response in band; resonance out of band
  - hysteresis, drift

Component characterizations (con't)

- position detectors
  - spatial uniformity of response, sensitivity
  - noise
  - linearity, saturation behavior
- equipment support structures
  - 'kinematicity'
  - response to ambient temperature changes
- optic reflectance
  - ensure sufficient R
  - no ill effects of $dR/d\nu$
- viewports
  - AR coatings
  - optical flatness

Complete Optlev system tests

Difficulty: to mimic LVEA environment

- foundation stability
- thermal stability
- acoustic conditions
- evacuated light path

Goal: to find tests which avoid this need

- if performance is very good, can test to specs on shorter baseline
- use of retroreflectors, multiple detectors to 'fit out' environment
- needs development

Worst Case

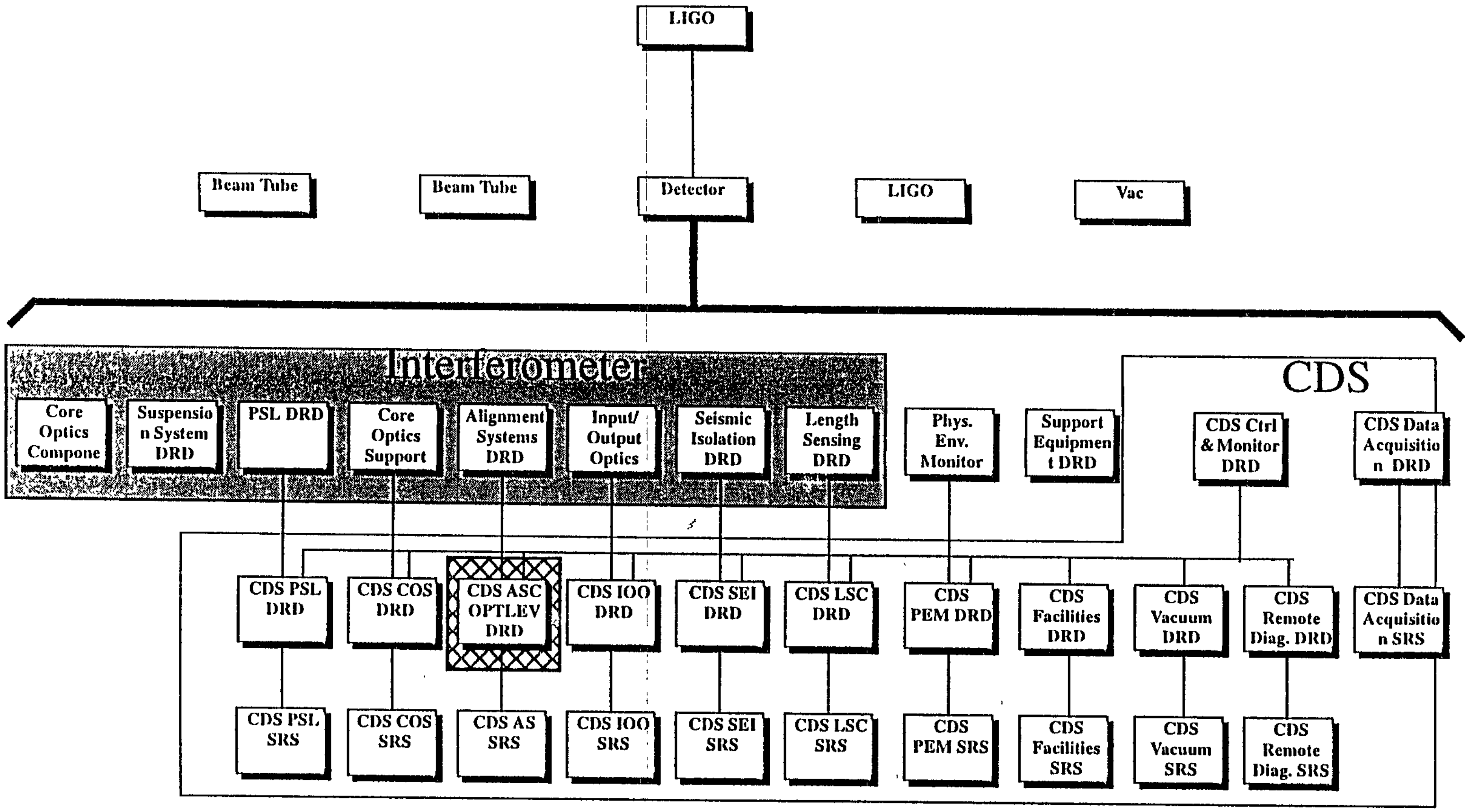
- need for ~5m evacuated path
- stable foundation
- quiet environment
- Draper/Lincoln/JPL?

ASC Optical Lever Electronics Design Requirements Review

November 13, 1995

J. Heefner

ASC Opt. Lev. Electronics Design Requirements



LIGO

Beam Tube
Beam Tube
Detector
LIGO
Vac

Interferometer

Core Optics Compone
Suspension System DRD
PSL DRD
Core Optics Support
Alignment Systems DRD
Input/ Output Optics
Seismic Isolation DRD
Length Sensing DRD
Phys. Env. Monitor
Support Equipment DRD

CDS

CDS Ctrl & Monitor DRD
CDS Data Acquisition DRD

CDS PSL DRD
CDS COS DRD
CDS ASC OPTLEV DRD
CDS IOO DRD
CDS SEI DRD
CDS LSC DRD
CDS PEM DRD
CDS Facilities DRD
CDS Vacuum DRD
CDS Remote Diag. DRD
CDS Data Acquisition SRS

CDS PSL SRS
CDS COS SRS
CDS AS SRS
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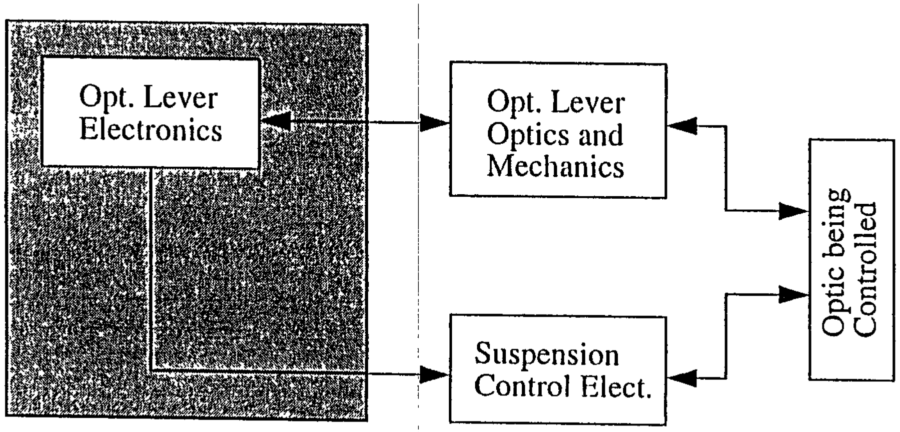
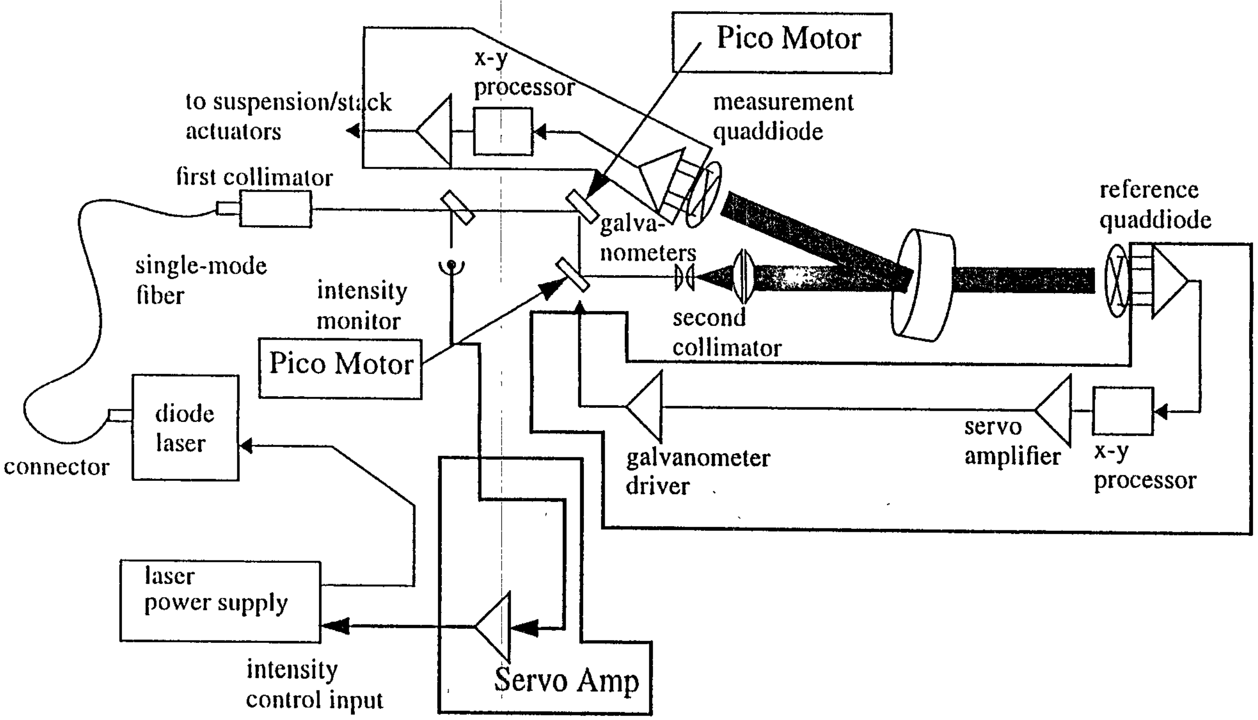
ASC Optical Lever Electronics Product Perspective



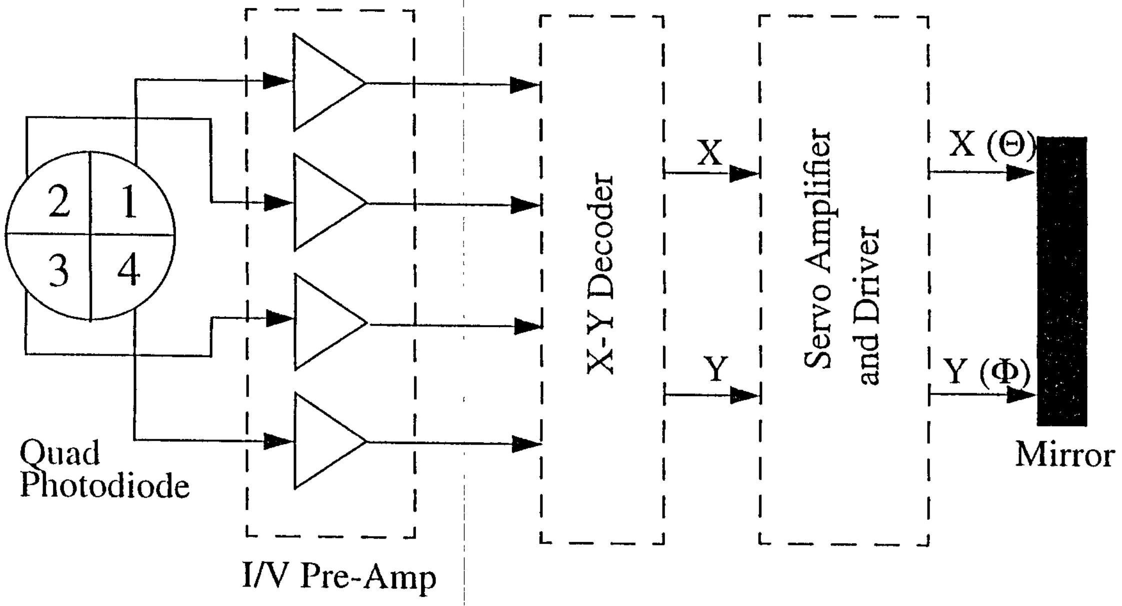
ASC Optical Lever Electronics Block Diagram



ASC Optical Lever Electronics Functions

- Beam and Mass Stabilization
  - ››Quad photodiode electronics and controls
  - ››X-Y position Decoder electronics and controls
  - ››Servo amplifier electronics and controls
- Rough Alignment/Pointing
  - ››Pico Motor electronics and controls
- Diode Laser Intensity Stabilization

Optical Lever Electronics Beam Stabilization



Optical Lever Electronics Beam Stabilization Requirements

- Quad Photodiode I/V
  - Gain: 1000 V/A
  - Input Noise: < $6\times10^{-12}\frac{\mathrm{A}}{\sqrt{\mathrm{Hz}}}$ for frequencies from 0.002 Hz to 10 kHz
  - Frequency Response: DC to 10 kHz
  - Output Drive: capable of driving 150 ft of twisted pair cable terminated in 1 kohm without degradation in performance
  - Temperature coefficient: < 200 ppm/C

Optical Lever Electronics Beam Stabilization Requirements (cont'd)

- X-Y Decoder
  - Transfer Function:

$$X = (Q1 + Q4) - (Q2 + Q3)$$

$$Y = (Q1 + Q2) - (Q3 + Q4)$$

  - Input Noise: $60\frac{\mathrm{nV}}{\sqrt{\mathrm{Hz}}}$ for 0.1 Hz< f<10Hz, $6\frac{\mathrm{nV}}{\sqrt{\mathrm{Hz}}}$ for 10 Hz<f<10kHz
  - Frequency Response: DC to 100 kHz
  - Temperature coefficient: < 1000 ppm/C

Optical Lever Electronics Beam Stabilization Requirements (cont'd)

- Servo Amplifier/Driver
  - ››Transfer Function:
    - — Nominal DC gain: 60 dB, with adjustment +/- 2 decades, and 1 dB incremental within a decade
    - — Simple LPF response with pole at 0.1 Hz. Provision for future poles and zeros
  - ››Output Noise:
    - —Mirror Driver: TBD with spurious spikes less than TBD
    - —Suspension Controller Driver: TBD with spurious spikes less than TBD
    - —Note 40 meter BPCU: less than $300\frac{\mu V}{\sqrt{\text{Hz}}}$ for 100<f<10kHz and less than $0.5\frac{V}{\sqrt{\text{Hz}}}$ .at 0.1 Hz. Spurious pikes less than 1 millivolt rms.

Optical Lever Electronics Beam Stabilization Requirements (cont'd)

- Servo Amplifier/Driver (cont'd)
  - ››Output Voltage and Drive:
    - —Mirror driver capable driving 100 feet of twisted pair cable termonated in 0.75 uF. Operating voltage from 0 to 150 volts. 75 volt output for zero volt input.
    - —Suspension controller driver capable of driving 100 feet of twisted pair cable terminated in 100 ohms to +/- 150 mA. Zero mA output for zero volt input.
  - ››Temperature coefficient: < TBD ppm/C
  - ››DC drift: TBD
- Controls and Monitors:
  - ››As described in DRD. In general, all parameters that can be adjusted and monitored will be adjustable and montiored via CDS.

Optical Lever Electronics Pico Motor Electronics/Controls

- Pico motors are used to maintain rough alignment of the mirrors used by the ASC optical lever.
- The motors and controllers are commercial units.
- CDS will be able to control the rate, direction and number of steps for the pico motor. The possiblity of future automatic centering software or algorithms shall not be precluded by the design.

Optical Lever Electronics Laser Intensity Controls

- Laser Intensity will be stabilized to better than TBD.
- System components will include:
  - Photodiode electronics
  - servo amplifier
- What about frequency stabilization? It is mentioned in T950112 para. 3.3.2, but nowhere else.

Optical Lever Electronics Physical Characteristics

- Optical Table Components
  - ››height adjustment capability
  - ››1/4-20 mounting bolts
  - ››cable connection and strain relief
- CDS Rack Mounted Components
  - ››All chassis shall be 19 inch rack mount.
  - ››All electronics modules shall be 6U VME card sized and designed in accordance with CDS specification TBD.
  - ››All cabling shall be in accordance with LIGO specification TBD.

Optical Lever Electronics Interfaces

- Detector Mechanical Interfaces

Table 1: Optical Lever Electronics Detector Mechanical Interfaces

Optical Lever Electronics Component	*Other System or Subsystem*	*Characteristics*
Quad Photodiode	ASC optical table	1/4-20 bolt

Optical Lever Electronics Interfaces

- Detector Electrical Interfaces

Table 1: Optical Lever Electronics Detector Electrical Interfaces

Optical Lever Electronics Component	*Other System or Subsystem*	*Characteristics*
Servo Amplifier	SUS Controller	0-150 mA into 100 ohms
Servo Amplifier	ASC mirror piezo	0-150 volts
Diode Intensity Stabilization Electronics	Diode Controller	TBD
Servo Amplifier	ASC Wavefront Sensing	TBD X and Y offset adjustments from wavefront sensing system

Optical Lever Electronics Interfaces

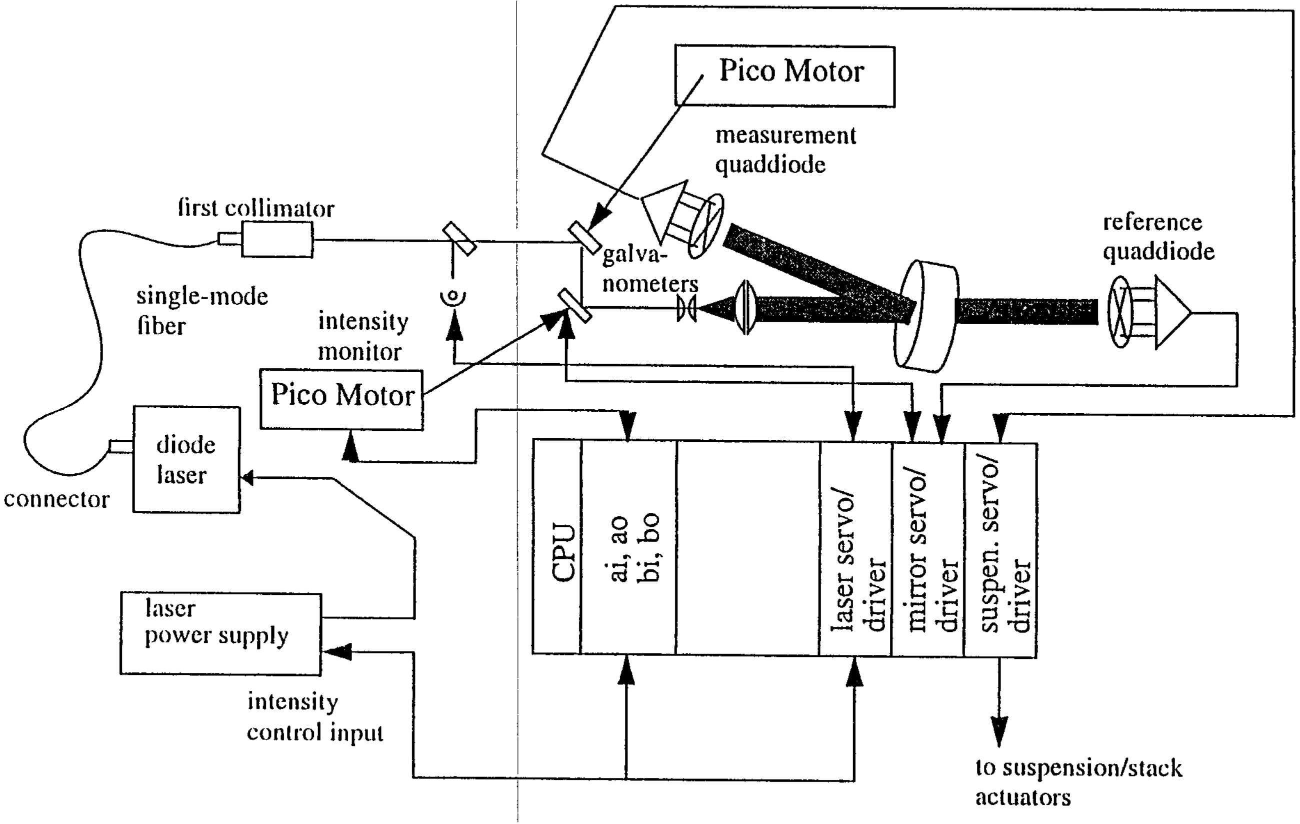
- Detector Optical Interfaces

Table 1: Optical Lever Electronics Detector Optical Interfaces

Optical Lever Electronics Component	*Other System or Subsystem*	*Characteristics*
Quad Photodiode	ASC laser light	10 mW, max.

- Non- Detector Interfaces
    - ››None

ASC Optical Lever Electronics Conceptual Design



Optical Lever Electronics Cost, Schedule, Risk Analysis

- Cost
  - ››Costs for manpower and hardware appear to be within the baseline
- Schedule
  - ››The schedule is being reworked in accordance with the replan
  - ››Current plan calls for delivery of prototype electronics by 4/96. CDS should be able to support this schedule.

Optical Lever Electronics Cost, Schedule, Risk Analysis

- Risk Analysis
  - ››Cost Risk: Low
    - —Hardware costs estimates are from quotes
    - —Manpower estimates are from exisiting jobs
  - ››Schedule Risk: Medium
    - —Manpower availability will be the limiting factor. CDS is currently in the process of staffing up
  - ››Technical Risk: Low
    - —Design and requirements are similar to those of the 40 meter BPCU
    - —There are no "state of the art" requirements to date, with the exception of the noise voltages at very low frequencies and the possibility of frequency stabilization.