COMPONENT SPECIFICATION

End Test Mass Telescope

APPROVALS:	DATE	REV	DCN NO	BY	CHK	DCC	DATE
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CHECKED:							
APPROVED:							
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1 SCOPE

This is a specification for the requirements of the optical system known as the ETM telescope. This device is an afocal, 3-element Galilean 8x beam reducer, which in combination with an optical relay system produces an image of the entrance pupil of the ETM PO telescope on the ISC quad photodetector. This detector is located on the ISC optical table adjacent to the BSC at the mid station and end station.

2 APPLICABLE DOCUMENTS

2.1. LIGO Documents

- LIGO-960641-05, Electronic Submissions to the Document Control Center
- LIGO-E960022, Vacuum Compatibility, Cleaning Methods and Compatibility Procedures
- LIGO-E960050, Vacuum Compatible materials list
- LIGO-L970196, Part Numbers and Serialization of Detector Hardware

2.2. Other Documents

MIL-C-675C, Coating Adhesion and Durability

3 REQUIREMENTS

3.1. Performance characteristics

3.1.1. Optical Characteristics

3.1.1.1 Clear Aperture

The mechanical assembly shall allow unobstructed passage of an entering 160mm diameter collimated optical beam centered on the optical axis, which exits through the output port as a 20mm diameter collimated beam.

3.1.1.2 Field of View

The operational field of view shall be, $\Delta\theta = \pm 2\times10^{-4}$ rad.

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3.1.1.3 Beam Reduction

The PO Telescope shall provide a nominal 8X beam reduction of a Gaussian intensity profile input beam. The Gaussian input beam waist parameter is $w = 46.4$ mm, located at the input aperture. The input beam diameter is 156mm.

3.1.1.4 Optical Transmissivity

The optical transmissivity through the telescope shall be >90% @ 1064 nm

3.1.1.5 Objective Lens (Element 1)

material	BK7
process	conventional polish
surface finish	40-20
surface roughness	<100 Ang.
edge	fine ground
edge bevel	45 deg
index of refraction tolerance	+/- 0.001
radius 1	368.3 +/-3.5
radius 2	-4494.2 +/- 9.9
wavefront aberration- power	<1 fringe @ 632 nm
wavefront aberration- irregularity	<1/4 fringe@ 632 nm
clear aperture diameter	170.0
edge diameter	176.0, -0.025 +0.0
central thickness	24.0, +/-0.5
wedge	<0.0340 TIR

3.1.1.6 Eyepiece 1 Lens (Element 2)

material	BK7
process	conventional polish
surface finish	40-20
surface roughness	<100 Ang.
edge	fine ground
edge bevel	45 deg
index of refraction tolerance	+/- 0.001
radius 1	78.88 +/- 0.1
radius 2	165.33 +/- 0.2
wavefront aberration- power	<1 fringes @ 632 nm
wavefront aberration- irregularity	<1/4 fringe @ 632 nm
clear aperture diameter	70.0
edge diameter	74.0, -0.025 +0.0
central thickness	15.0, +/-0.2
wedge	<0.070 TIR

3.1.1.7 Eyepiece 2 Lens (Element 3)

material	SF6
process	conventional polish
edge	fine ground
surface finish	40-20
surface roughness	<100 Ang.
edge bevel	45 deg
index of refraction tolerance	+/- 0.001
radius 1	-64.39 +/- 1.0
radius 2	70.49 +/- 1.0
wavefront aberration- power	<1 fringe @ 632 nm
wavefront aberration- irregularity	<1/4 fringe @ 632 nm
clear aperture diameter	40.0
edge diameter	44.0, -0.025 +0.0
central thickness	10.0, +/-0.5
wedge	<0.040 TIR

3.1.1.8 Antireflection Coating

Applied to both surfaces of all three elements

coating efficiency	>99.5 % transmissivity per surface
operating wavelength	1064 nm
Incidence angle	Normal
Durability	MIL-C-675C

3.1.2. Mechanical Characteristics

The optical center line of the ETM telescope (see Fig.5) will be suspended by a vertical support column below an optical table. The ETM telescope shall be attached to the support column so as to enable 4 degrees of freedom. That is, the optical barrel shall be moveable transverse to the optical axis in the horizontal and vertical planes, and shall tilt in pitch and yaw to the following limits:

- V-plane:+/- .5 inches total, +-.020 inches fine adjustment
- H-plane:+/- .5 inches total, +-.020 inches fine adjustment
- Yaw axis:+/- 2 degrees total, +-1minute fine adjustment
- Pitch axis:+0.0/-3 degrees total, +-1minute fine adjustment
- Position of optical axis below optical table: 600mm

A removable bracket shall be provided at the output of the ETM telescope, for attaching a commercial mirror mount to be oriented at 45 degrees. (see Fig.5)

3.1.2.1 Mechanical Tolerances

The assembly shall be designed to maintain the optical element's mounting tolerances (Fig 1) as follows

- Mounting ID, Lens 1= 176.05mm +0.05 / -0.00mm
- Mounting ID, Lens 2= 74.05mm +0.05 / -0.00mm
- Mounting ID, Lens 3= 44.05mm +0.05 / -0.00mm
- Tilt = 0.056 degree max
- Mechanical decenter = 0.2mm

3.1.2.2 Focus compensation

- Separation between elements L1 and L2 = 369.476mm, +/-12mm
- Separation between elements L2 and L3 = 81.523mm, +/-5mm

3.1.2.3 Mechanical Vibration Characteristics

The telescope, and its associated mounting structure shall have no internal mechanical resonances <100Hz.

3.1.2.4 Size and Weight

- Maximum size envelope - 30l x 10w x30h inches
- Maximum weight of telescope, and its associated mounting structure- <45 pounds

3.2. DESIGN AND CONSTRUCTION

3.2.1. Materials

3.2.1.1 Mechanical Parts

3.2.1.1.1 Allowed Materials

It is desired that aluminum be used for all metal components, to the greatest extent possible. All materials must conform to LIGO document "LIGO-E960050, Vacuum Compatible materials list". No anodizing or lubricants are permitted. Care must be taken in selecting materials which are threaded or slide against one another, to prevent galling. Some elastomers may be allowed subject to approval by cognizant technical personnel.

3.2.1.1.2 Part Machining

3.2.1.1.2.1 Liquid contaminants/Machining Lubricants

Liquids containing hydrocarbons or other contaminants, other than the machining fluids specified herein, shall not be allowed to come into contact with suspension material at any time. All machining fluids shall be water soluble and free of sulfur, chlorine and silicone; such as Cincinnati Milacron's Cimtech 410 (stainless steel).

3.2.1.1.2.2 Grinding & Abrasive Cloth/Paper

Grinding (with abrasive wheels, cloth, or stones), or use of abrasive cloth or paper, is permitted, except where noted, if the ground or impacted surface is subsequently skimmed with a carbide tool to remove any residual contaminants. The use of oil free Arkansas stones are also approved to remove slight imperfections in the machined surfaces.

3.2.1.1.3 Dry Film Lubricants

Generally acceptable practice to prevent galling is too use stainless steel (CRES) hardware in aluminum substrate, or silver coated CRES hardware in CRES substrate.

3.3. Quality Assurance/Control

3.3.1. Identification

Separate (non-welded) parts and assemblies shall be marked with laser marking or acid etch techniques. A vibratory tool with a minimum tip radius of 0.0005” is acceptable for marking on surfaces which are not hidden from view. Engraving is also permitted.

Separate (non-welded) parts and assemblies to be serialized according to the document titled Part Numbers and Serialization of Detector Hardware, LIGO-L970196. This document allows for “bag-and-tag” type of identification for small parts.

3.3.1.1 Serial Number

3.3.1.2 Optical Serial Number

A serial number identifying a component set of elements shall be etched, ground or sandblasted on the edge of each element.

3.3.1.2.1 Serial Number Format

The Serial number shall be of the format: E980328-y S/N *e-nnn*, where E980328-y is the LIGO specification number, E980328, including the revision letter, -y, to which the lenses were built; *nnn* is the sequential serial number, 001 through 999, in the order produced, and e=1, 2 or 3 describes the objective (e=1), eyepiece 1 lens (e=2) or eyepiece 2 lens (e=3).

3.3.1.3 Mechanical Part Number

A part number shall be etched, ground or sandblasted on each manufactured component of the telescope housing.

3.3.1.3.1 Part Number Format

The Part number shall be of the format:
Dxxxxxx-y, Where Dxxxxxx-y is the LIGO drawing number, Dxxxxxx, including the revision letter, -y, to which the hardware item was built.

3.3.2. Quality Assurance Provisions

A first article shall be produced and inspected for form, dimensions and workmanship.

3.3.3. Purchaser Access

Non-escort privileges for the buyer, owner, government and owner representatives to all areas of the facilities where work is being performed shall be arranged. This will include access to all areas where material is being processed and stored. The purchaser shall have the right to witness all manufacturing processes.

3.3.4. QA Approval

LIGO QA reserves the right to inspect and approve vendor/fabricator QA plan and processes.

4 TEST PROCEDURES

The assembled telescope performance shall be verified by the following test procedures

- TBD

4.1. Transmissivity

Transmissivity measurement across clear aperture, @1064nm wavelength

4.2. Vibration Test

- TBD

5 DOCUMENTATION

- 1) Vibration analysis
- 2) Working drawings for component parts, in AutoCad 14 format on LIGO title block
- 3) Top assembly drawing, in AutoCad 14 format on LIGO title block
- 4) DOD-STD-100,MIL-STD-1000 and ANSI-Y14.5M 1982 standards applied where appropriate

- 5) Compliance Certification for items 3.1, 3.2, 3.3 and 4.0

6 ENVIRONMENTAL CHARACTERISTICS

The PO Telescope will operate in a non-vibrational, ultra high vacuum environment, at room temperature (68F,+/-4F).

7 HANDLING AND SHIPPING PROCEDURES

7.1. Cleaning

Approved cleaning procedures for UHV components are detailed in LIGO-E960022, Vacuum Compatibility, Cleaning Methods and Compatibility Procedures.

7.1.1. Optical Surfaces

All optical surfaces shall be cleaned in accordance with good commercial practice. Nothing shall contact the optical surfaces after cleaning, except for lint-free lens tissue.

7.1.2. Mechanical Parts

Mechanical parts shall be degreased in a clean solvent.

7.1.3. Disassembly for Cleaning

The ETM Telescope assembly will be disassembled for cleaning of all components. All surfaces shall be cleaned in accordance with good commercial practice.

7.2. Packaging for Shipment

7.2.1. Optical Parts

The cleaned and disassembled optical components shall be protected with 6 layers of lint-free lens tissue, and placed in a sealed, clean polyethylene bag before shipping.

7.2.2. Mechanical Parts

The cleaned and disassembled mechanical components shall be placed in a sealed, clean polyethylene bag before shipping. Dissimilar components will not be mixed, but individual components of a like kind may be placed in a single bag, and tagged according to their part number (see sec 3.3.1.3.1).

8 DESIGN OF PO TELESCOPE

The optical design of the ETM Telescope is shown in figures 1, 2, 3, and 4. The mechanical design is shown in figure 5.

8.1. Optical design

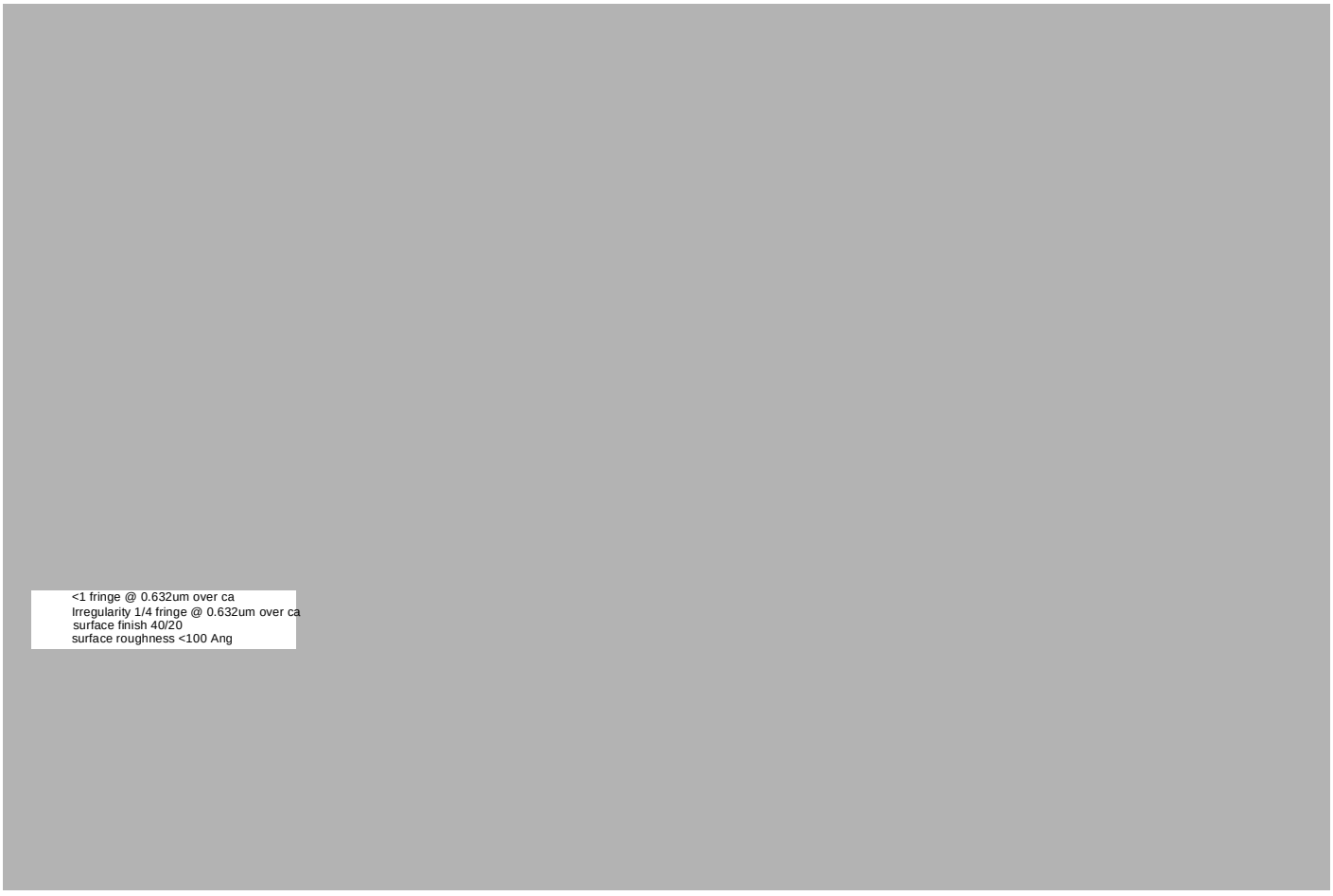

Figure 1: ETM Telescope, optical layout

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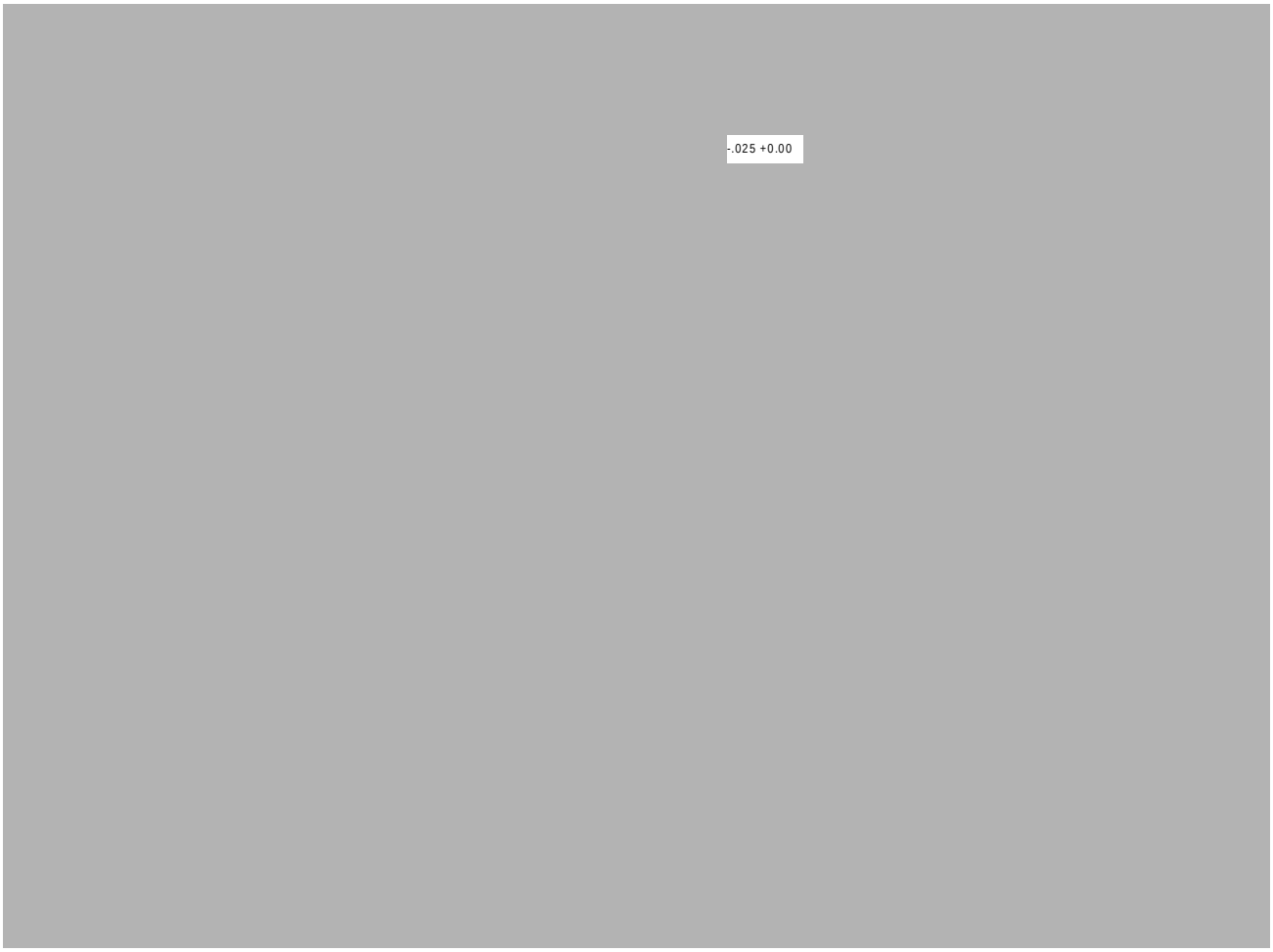

Figure 2: Objective lens (Element 1), ETM telescope

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Figure 3: Eyepiece 1 lens (Element 2), ETM telescope

Figure 4: Eyepiece 2 lens (Element 3), ETM telescope

8.2. Mechanical Design

Figure 5: ETM Telescope, mechanical layout