KAON # 749

Next Generation Adaptive Optics System

Laser Guide Star Facility

Laser Enclosure

Preliminary Design

May 04, 2010

VersionV1.0

Prepared By J. Chin

REVISION HISTORY

Revision	Date	Author (s)	Reason for revision / remarks
1.0	May 04, 2010	All	Preliminary Design Release

TABLE OF CONTENTS

1 INTRODUCTION

As part of the Next Generation Adaptive Optics System (NGAO), a Laser Enclosure (LE) is required to house the NGAO lasers (3) as well as the Switchyard (SYD). These two subsystems are housed in a LE that is attached to the Keck II telescope elevation ring. During the system design phase as documented in KAON 511, the requirements for the LE were a major concern due to the lack of knowledge of the NGAO lasers. Since the Systems Design Review, significant effort has been spent to address the NGAO lasers and their requirements. With a better understanding of these requirements, the LE design has been significantly simplified to a point where a new LE is unnecessary. Instead of providing a new design during the preliminary design phase, this document provides the justification for reusing the existing Keck II LE. This simplification will also reduce the overall resources required by the NGAO project. Following the justification, the document will go into each requirement and address its compliance.

2 REFERENCES

2.1 Referenced Documents

Documents referenced are listed in Table 1. Copies of these documents may be obtained from the source listed in the table.

Ref. #	Document #	Revision or Effective Date	Source	Title
1	KAON 511	0.3	WMKO	NGAO System Design Manual
2		1.0	WMKO	LE Requirements Compliance Document
3		1.0	WMKO	Safety System ICD Spreadsheet
4		1.0	WMKO	NGAO LGSF LE DD (MS Project)

Table 1: Reference Document

2.2 Acronyms and Abbreviations

Table 2 defines the acronyms and abbreviations used in this document.

Acronym/Abbreviation	Definition
AO	Adaptive Optics
BTO	Beam Transfer Optics
ICD	Interface Control Document
KAON	Keck Adaptive Optics Note
LE	Laser Enclosure
NGAO	Next Generation Adaptive Optics System
SYD	Switch Yard
WMKO	W.M.K. Observatory

Table 2: Acronyms and Abbreviations

3 OVERVIEW

The current LGSF layout is shown in Figure 1 which is similar to the layout presented in the NGAO System Design Review (KAON 511) except for the location of the laser enclosure. The System Design layout assumes all three laser systems and the SYD can fit in a single large enclosure on the Nasmyth platforms or a new platform between the AO Enclosure and the Cassegrain platform (Figure 2). The advantage of this design is that there isn't a changing gravity vector requirement for the laser systems; the difficulty is to transport the laser beams from a fixed gravity location to a gravity dependent location on the elevation ring. In the current design, the beam transport system is made simpler by locating the laser enclosure on the elevation ring. The drawback of this layout is the requirement that the laser must function in a moving gravity environment.

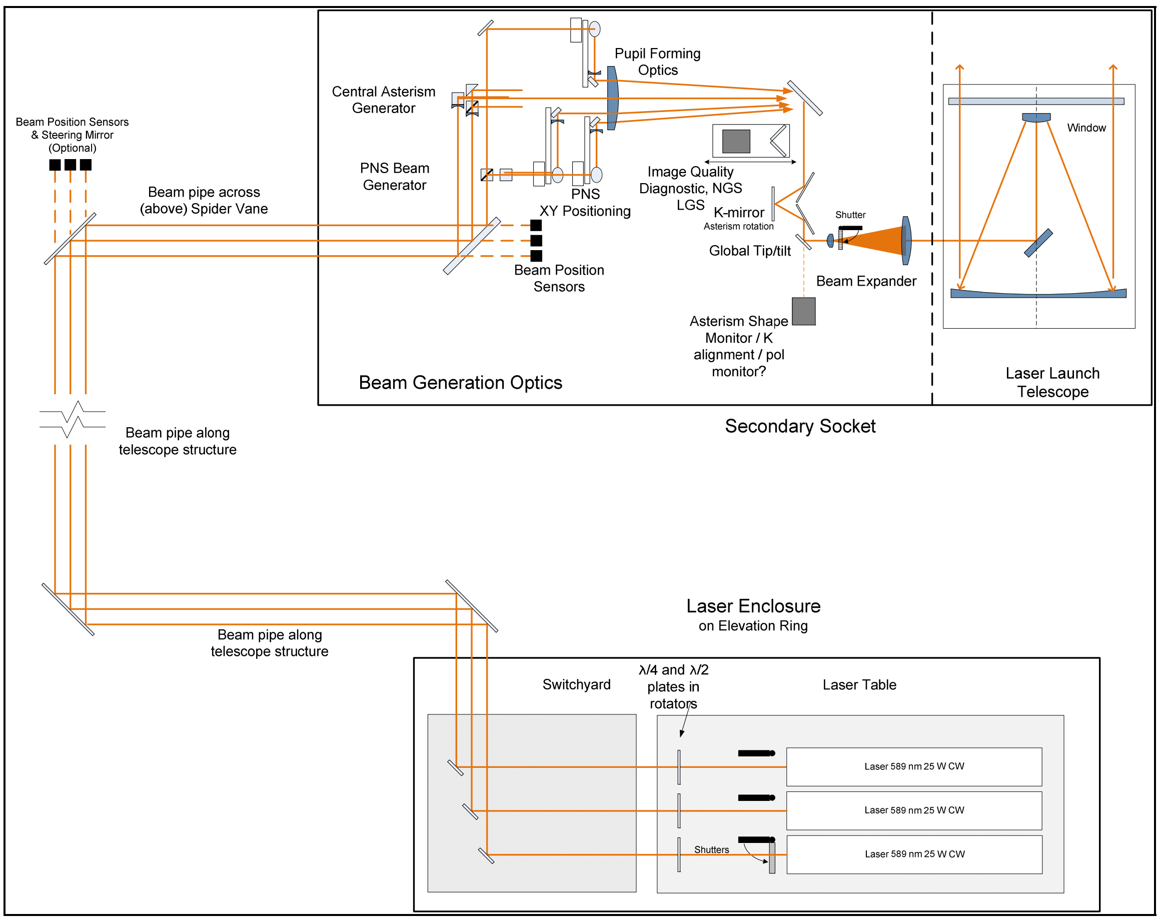

Figure 1: Laser Guide Star Facility

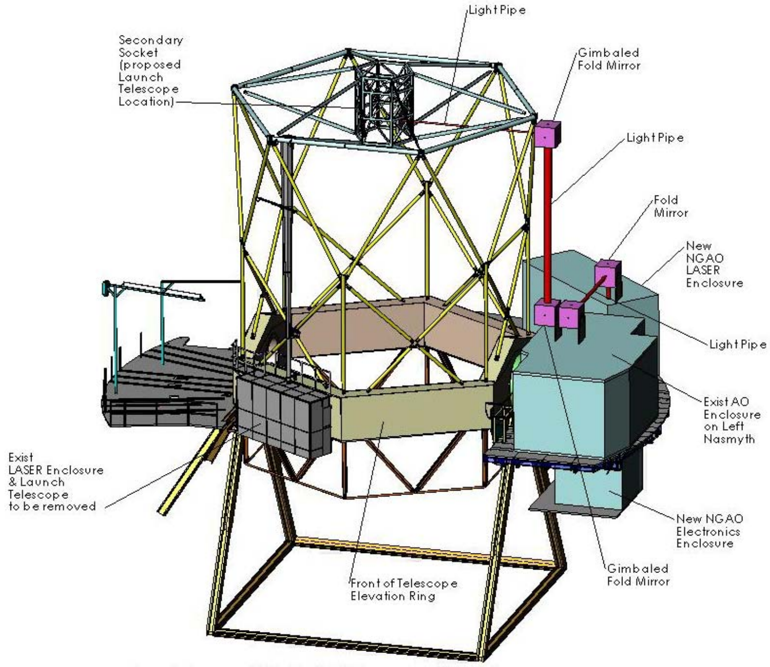

Figure 2: New Laser Enclosure Design

The current laser design is sufficiently advanced that it will be possible to locate them with a changing gravity vector making the current LE design attractive. To make this possible, the lasers themselves must be small enough to fit in an area similar to the existing Keck II laser table. Each laser has been separated into two assemblies called the *Split Relay System.* The pump lasers/control system provides the laser diodes generating the pump lasers, the seed laser, and the overall control system are located in the AO electronics vault. The laser head that produces the 589nm laser beam and is located in the LE. The interface between the two systems is comprised of control signals, fibers that transmit the pump light, and the cooling lines. The distance between the two systems is expected to be less than 40 meters. The laser layout is shown in Figure 3.

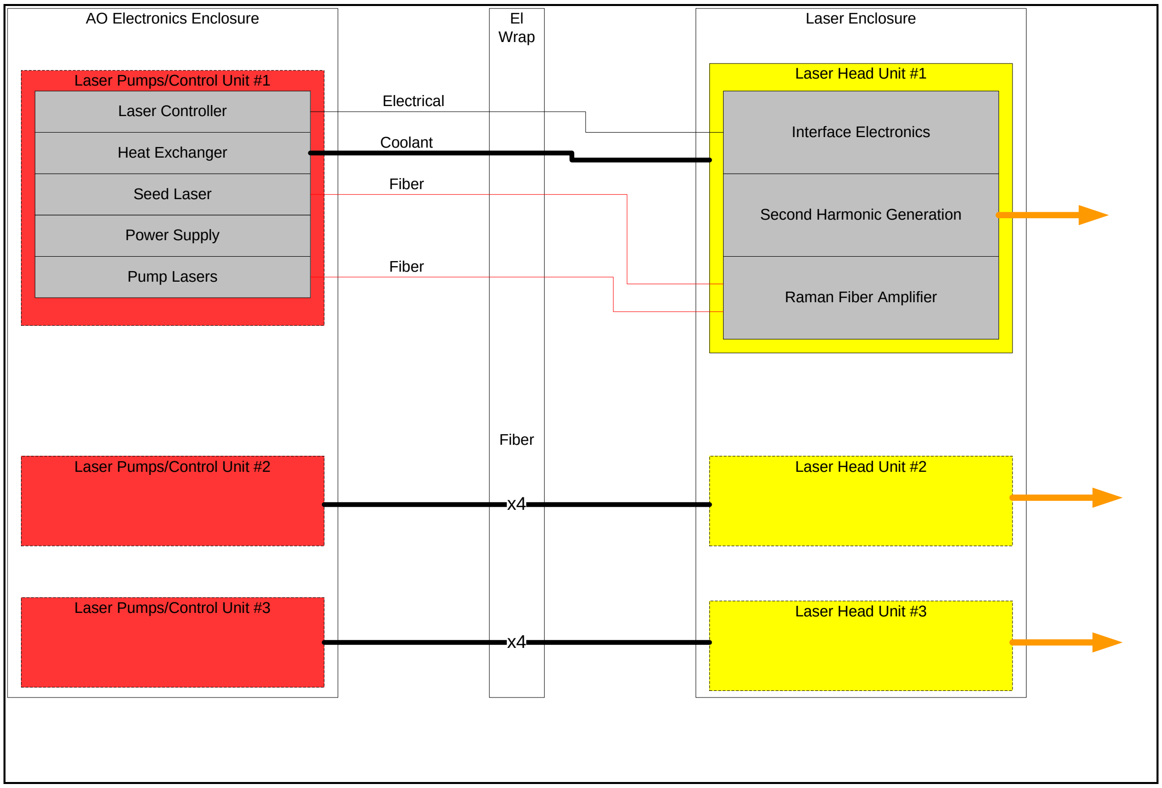

Figure 3: Lasers Layout

4 LASER ENCLOSURE LAYOUT

4.1 Existing Layout

The existing Keck II LE is shown in Figure 4. The room is light tight except for a small window for output of the current Keck II laser. The room is access via the right Nasmyth platform when the telescope is rotated to the zenith position. At the zenith position, the current laser table located within the LE, can be serviced and maintained.

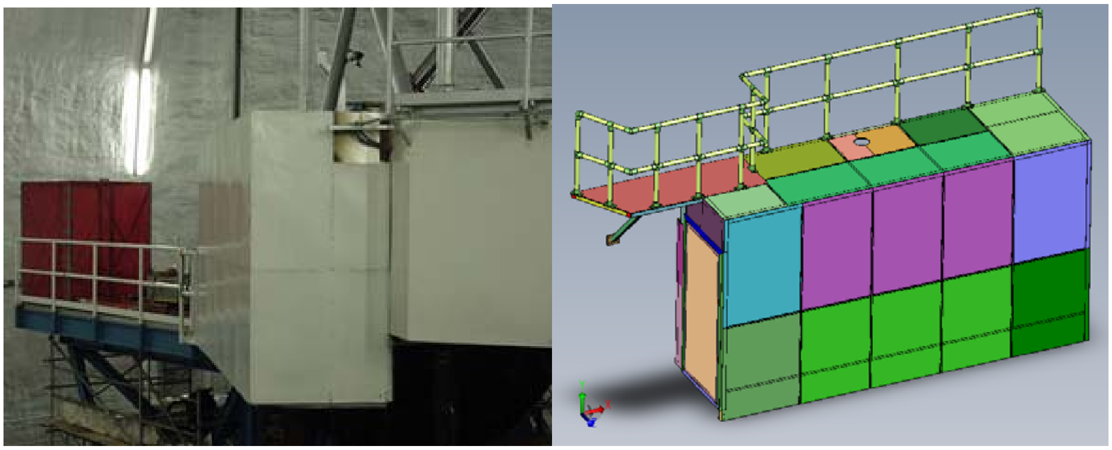

Figure 4: Laser Service Enclosure

Figure 5: Laser Service Enclosure and Optical Bench for the Keck II Laser System

Figure 6 shows the existing laser table (purple) within the LE. The LE exterior panels have been made transparent in this figure to facilitate viewing. On the right of the laser table is an electronics rack that supports the mechanisms within the laser table. In the new LE layout, the existing laser table and supporting electronics will be replaced with a new structure supporting the three new laser heads and SYD.

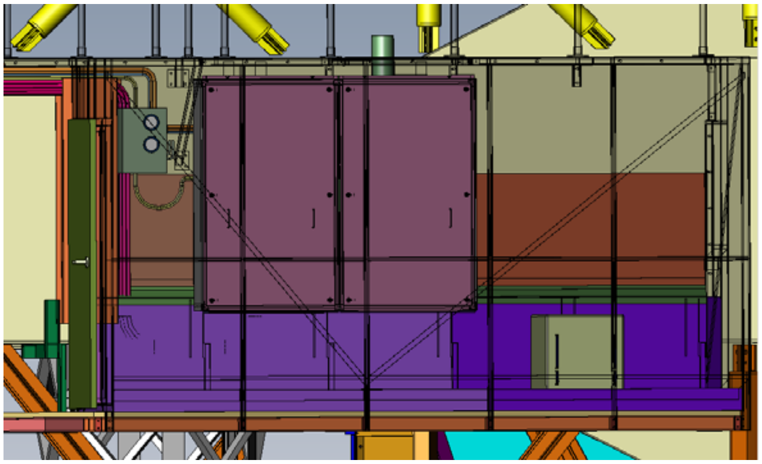

Figure 6: Existing Laser Bench inside LE

4.2 Layout of NGAO Laser System

Figure 7 shows the new layout of three lasers within the existing LE. The size of the laser heads (yellow) has been chosen based on the laser manufacturer's PDR. The blue area is the SYD which formats the three beams and relays them onto the Beam Transport Optics (BTO). To minimize flexure, all three lasers heads and the SYD opto-mechanical components will be mounted onto a single rigid frame. This frame will be attached to the elevation ring similar to the existing Keck II laser design. The frame will be stiffened at the mating points to the lasers and SYD as well as the six attachment points to the elevation ring. The attachment points are shown in green in Figure 8 and Figure 9 (Additional bracing will be added over these pads).

The existing laser table will be removed as a single unit and the new laser assembly will be attached as a single unit. Once installed, the laser unit and the SYD can be removed individually for maintenance and servicing as needed. Additional hardware mechanisms will be required to insure alignment repeatability and accuracy. Any misalignment can be removed by the tip-tilt stages within the SYD.

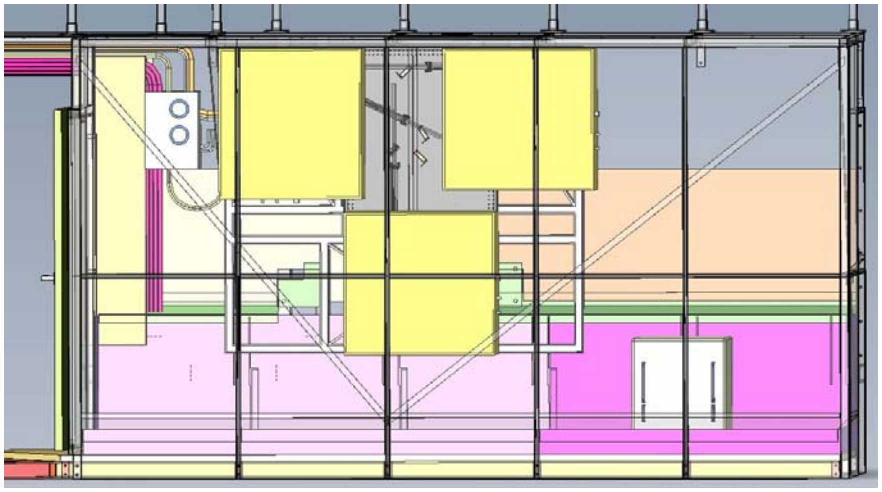

Figure 7: New Laser Enclosure Layout

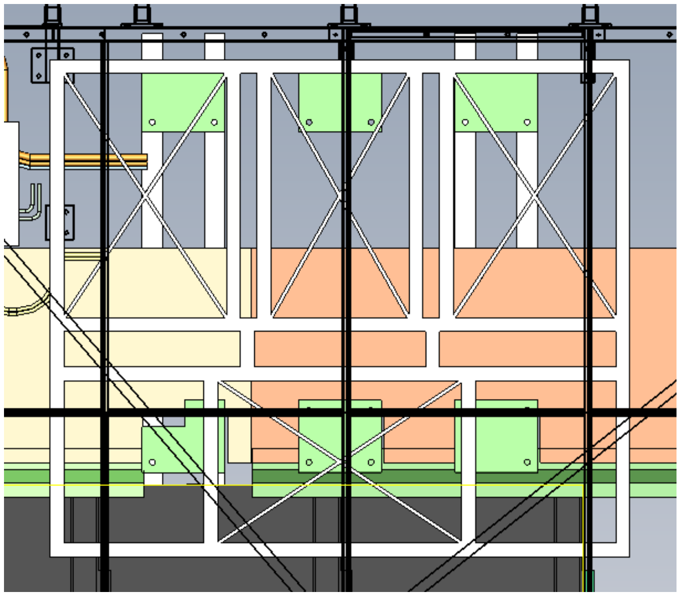

Figure 8: Lasers and SYD Support Frame

4.3 Mass Allocation

To minimize any impact to the telescope, the design of the lasers and the SYD should not exceed the weight of the existing laser table and auxiliary equipment. Table 3 shows the estimated mass of the components based on the laser PDR data. The new system will weigh 585 Kg less than the existing laser table. This reduction in weight may have a doubling impact on the telescope as an additional 585 Kg may be removed from the back of the elevation ring for balance purposes.

	Keck 2 Laser (Kg)	New Laser (x3) (Kg)
Laser Table	1136	536
Mounting Bracket	75	125
Laser Cabinets	60	60
Dye lines/fittings/Cooling	30	30
Cabling	50	15
Total	**1351**	**766**

Table 3: Estimated mass for laser and auxiliary equipments

4.4 Laser Enclosure support

4.4.1 Laser Installation and Servicing

Although the existing laser enclosure does not have to be replaced, some modifications will be necessary to support the new lasers. The laser(s) and the SYD will be installed similarly to the method completed for the Keck II laser. The Keck II laser table was installed as a single unit (Figure 9) prior to installation of the LE. The NGAO laser(s) and SYD will require the LE exterior to be removed first prior to installing the laser(s) and SYD. It is reasonable to assume that not all three NGAO lasers will be installed at the same time. In which case, the panels above the LE will be removed for access with the 5-ton jib crane once the initial system is in place. This will require modifications to the top of the LE. The modifications will be determined once the lasers and SYD are located to match the BTO.

The estimated distance between the lasers/SYD and the LE panel wall is 24”. This will allow personnel to be standing in front of the units for any alignments and service.

Figure 9: Laser Mounting onto Elevation Ring

4.4.2 Temperature, Particulates and Humidity

The individual laser heads will be treated as black boxes and will have their own internal environmental controls. The LE will not require additional temperature and humidity control to support the lasers. However, it is prudent to provide diagnostic monitoring of the interior to ensure the LE is within the expected the operational parameters. An existing *ACKP* humidity and temperature sensor can be reused if necessary. This sensor is already interfaced into the observatory's EPICs control system. The data will be used for monitoring as well as possible in-situ servicing of the lasers. However, a particulate sensor is not available. A new particulate sensor including humidity and temperature can be purchased for ~$3K. WMKO currently owns the Met-One GT-521 unit. The advantage of this unit is that it has a serial port for data capture and remote control if necessary.

4.4.3 Lighting and Ventilation

The LE has existing lighting and will not require additional modifications. An existing fan on the LE provides makeup air for personnel in the LE. The fan will activate only when the lights are on. During normal night time observations, the lights and fan are off to not impact the telescope.

4.4.4 Electrical Power

The laser heads will receives its power from the laser controller inside the AO e-vault. The remaining power requirement for the SYD and lighting will not exceed the 120AC 20A circuit already existing in the current LE. All electrical connections will remain within the LE.

	Required (W)
Environmental Sensor	20
Lighting as need	100
Test Equipment as needed	300
HEPA filtration as needed	100
Total	**520**

Table 4: AC Power Requirements

4.4.5 Cooling

Each laser will be insulated to minimize its heat transfer impact to the LE. Based on the estimated temperature analysis by the laser manufacturer, the surface of the laser head will be 1.5°C. Assuming a 0.5 meter^2 surface, the heat transfer to the ambient will be approximately 4.5W per laser if the ambient is 0°C. Assuming worst case conditions of -5°C, each laser will transfer 19.5W into the LE environment. Three lasers will total 58.5W, above the 50W threshold. To reduce this heat load slightly, a cold plate can be added to the mounting frame structure or near the laser heads using existing instrument glycol at the LE.

The SYD will require instrument glycol cooling for the beam dumps. 75W of laser power will be transferred to the glycol with an additional 25W of cooling for the SYD electronics. There may also be additional electronics heat in support of the control system and safety system. An estimate of 100W is added to support these functions. The total cooling requirements is shown in Table 5.

	Cooling (W)
Laser Head x 3	59
Laser Power x 3	75
SYD electronics	25
Control and Safety System Electronics	100
Total	**259**

Table 5: Instrument Cooling Requirements

4.4.6 Communications

The current Keck II LE has both CAT5 and phone communications available. No additional resource will be necessary.

4.5 Safety

4.5.1 Eye Safety

The existing LE is a Class IV laser enclosure and has the proper interlocks in support of the Keck II laser as well as the NGAO lasers and SYD. These include door switches and LED status for incoming personnel. The lasers and the SYD will have independent covers or shielding to prevent stray light from exiting the LE. All existing safety features will be reused and tied into the new NGAO Laser Safety System. These include E-Stops, door interlocks, and panel interlocks..

Laser status indicators shall be provided at entry point to the LE as well as its interior. The indicators will be represented in Table 6. The indicators already exist on the exterior of the current LE. Interior indicators will provide status to the operator when opening laser and SYD panels. The existing Keck I laser panel design can be replicated.

	Status Level	**Status Description**
1	Green	No hazardous radiation in the LE
2	Orange	Hazardous Radiation exists in the LE and it is contained; proceed with caution
2	Red	Hazardous radiation exists in the LE; do not enter

Table 6: Laser Status Indicator Definition

4.5.2 Fire Safety

A portable Ansul Cleanguard® type fire extinguisher shall be provided similar to the Keck I LE. The technology of the NGAO lasers does not require an automatic type fire extinguishing system as implemented on Keck I. In addition, an extinguishing system may not operate effectively in a changing gravity vector situation. A smoke detector will be available as part of the safety system.

4.5.3 Operational Safety

Either for service or in case of emergency, a switch shall be located at the LE to disable the laser shutters. The switch will be an input to the safety system and will remove the hardware shutter permissive to the laser systems. This will prevent any laser beams from entering the SYD optics during servicing. The Emergency Stops located inside and outside of the LE will terminate any laser radiation.

4.6 External Interfaces

4.6.1 Mechanical Interface to the elevation ring for the LE

No new interfaces are necessary as the current LE has an interface in place.

4.6.2 Infrastructure Interfaces

Existing interfaces will be used for glycol, electrical, pneumatics, and phone; which are in place at the current Keck II LE. An existing dry air purge will be reused to keep a positive pressure in the room. A number of infrastructure connections will pass through the LE; but not connected to the LE. These include cabling for the lasers and the SYD.

Ref #	Device Types	Connection	Connection	Quantity	From	Note	Format
1	Glycol	Supply Return	Copper	1	Telescope Instrument Cooling	In place	Glycol
2	Electrical	5-wire	Duplex	3	Elevation Ring Breaker Panel	In place	AC 120
3	Pneumatics	Supply Return	Copper	1	Telescope Pneumatics	In place	Dry Air
4	Phone	8 wire	RJ-45	1	Keck II Mechanical Room	In place	Low DC Voltage Analog

Table 7: Infrastructure Interfaces

4.7 Internal Interfaces within the LGSF

4.7.1 Mechanical Interface for the Laser and SYD

The mount for the SYD and lasers will be attached to the elevation ring. This bracket will be delivered as part of the LE. It will include mounting interfaces for the laser, SYD and itself to the six elevation ring mounting pads as shown in Figure 10.

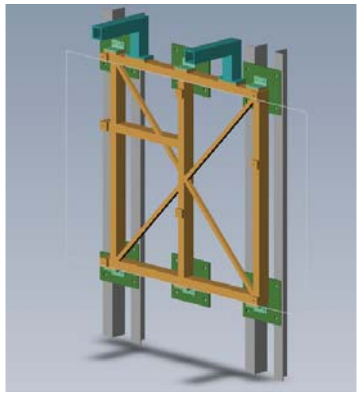

Figure 10: Current Keck 2 mounting support structure

4.7.2 Mechanical Interface to the Beam Transfer Optics

A new interface with the Beam Transport Optics will be necessary. The interface will be similar to the existing L4 tube in Keck II (Figure 11, without offset). The new interface will be smaller since the beams are 1mm in diameter. The tubes will be metal tube structures sized 4" x 1". A window will be implemented similar to the existing Keck II design to prevent turbulence due to the chimney effect. It may be possible to reuse the existing window; depending on the configuration of the lasers leaving the LE.

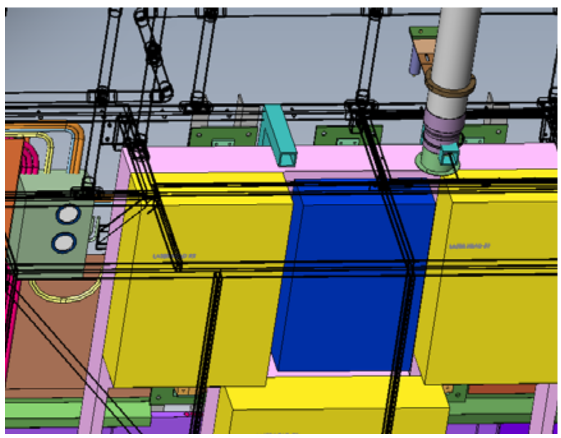

Figure 11: Launch Tube Interface

4.7.3 Electronic Interfaces

The LE primary electronics interface will be with the safety system in the AO electronics vault. A number of cables will pass through the LE; but not connected to the LE. These include cabling for the lasers and the SYD. For the LE itself, an interface unit for two Mil-Spec connectors will be provided. One connector will be for input and one connector will be for outputs to the safety system. The signals are listed in the Safety System ICD Spreadsheet.

In addition to the safety system, environmental devices will be used to monitor the health of the LE. The LE is expected to have a particulate monitoring system and a temperature/humidity system. These monitors will require a RS232 and CAT5 interfaces.

Ref #	Device Types	Connection	Connection	Quantity	From	Note	Format
1	CAT5	8 wire	RJ-45	4 (2 spare)	AO E-vault	In place	Low DC Voltage Digital
2	Digital I/O	Multi- wire	Mil-Circular, DB	2	Safety System	Interlocks	Low Voltage Digital
3	Digital I/O	15-wire	DB-15	1	AO E-vault	RS-232	Low Voltage Digital

Table 8: Electronic Interfaces

5 Operations

5.1 Maintenance and Service

Standard maintenance at the LE includes cleaning and/or replacing of filters for the pneumatics, HEPA system and environmental sensing system, cleaning of the exit window to the BTO, and a bi-annual wipe down of the inside of the LE. The environmental sensor will need a re-calibration every two years. Safety related checks will be covered by the safety system. The effort required for this is in the order of 1 person-day per year and a procurement of $400. The telescope must be in the zenith location to allow this maintenance.

6 Integration & Test

Laser Enclosure I&T will be supported in WBS 9.2 laser Enclosure Integration.

7 Requirements Compliance Verification

The compliance matrix is presented in the overall LGSF Compliance Matrix. Most of the requirements are met by using the existing Keck II laser enclosure. Table x shows the requirements that require further explanation; these requirements are not met in the preliminary design phase, partial compliance, or not applicable.

8 DELIVERABLES

Figure 12 shows the deliverables for the LE.

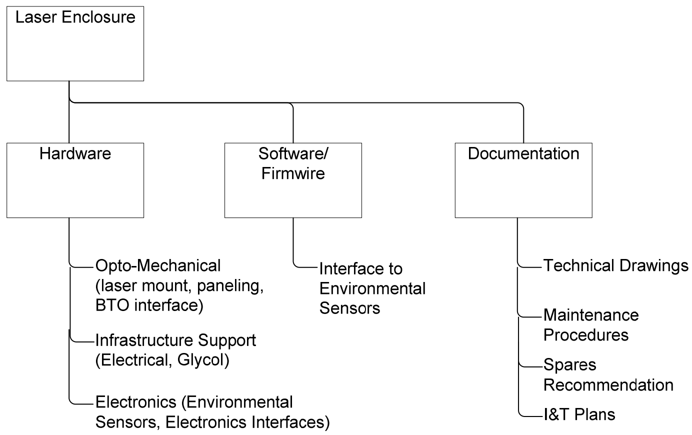

Figure 12: Laser Enclosure Deliverables

9 SYSTEM COMPLIANCE

The compliance of this system is provided in the overall LGSF Compliance Matrix. The following table shows the requirements that need further examination or explanation.

Short Name	ID	Description	Proposed Final Verification Method	Compliant at PD Phase	Comments
Enclosure temperature	FR-1283	The acceptable laser enclosure operating temperature is -10° to +10°C. Based on the current ESO laser proposals, the ambient dome temperature is acceptable for laser operations. However, the optical switchyard and laser supporting equipment cooling requirements must be evaluated for operation in this temperature range.	Design	DD	DD; must be verified with controls team.
Ladder	FR-1317	Mechanical: The laser service enclosure shall provide a ladder to the roof if access to the roof of the enclosure is necessary. The ladder may require additional caging to protect personnel during ascent and descent if deemed necessary by the Safety Officer. May not be necessary if there is some other means to get on the roof. TBD.	Design	N/A	No roof access provided on existing LE; not meant to be walked on.
Weight load on roof	FR-1318	Mechanical: The roof of the laser service enclosure shall be able to support 2 people and its environmental controller (e.g., HVAC), as required. TBD.	Design	N/A	No roof access provided on existing LE; not meant to be walked on; no plans for equipment on roof
AC Power format	FR-1296	The laser service enclosure shall provide sufficient power for the laser, laser electronics, diagnostics, lights, and internal HVAC equipment to maintain routine operation. The power shall be 3 phase, 208 VAC, 60 Hz. The power factor shall be no less than 0.85.	Design	Partial	Laser AC power needed at AO e-vault; existing power available; power factor specified for laser manufacturer
Environmental Controls	FR-1300	The laser service enclosure shall provide control of temperature and humidity to meet the requirements of the laser and supporting equipment. The normal operating temperature range shall be TBD. The maximum rate of temperature change shall be no greater than TBD. The normal operating humidity range shall be TBD.	Design	N/A	Not required by laser manufacturer

		Based on ESO laser proposals, the lasers do not require environmental control.			
Emergency lighting	FR-1322	Electrical: The laser service enclosure shall have emergency lighting for egress in case of power failure.	Test	N/A	In the current laser enclosure, it was deemed sufficient for "glow in the dark" signs; also LSO suggests the cabinet layout is sufficiently simple that emergency lighting is not needed.
Electical panel	FR-1330	Electrical: The laser service enclosure shall have a single electrical panel on the outside of the enclosure for all power entering the enclosure. This panel shall provide the properly sized breakers for individual connections within the enclosure. The panel shall provide a shunt trip for emergency shutdown of all power.	Test	N/A	The laser units will be sealed. The laser interface provides a means to shut off radiation in case of emergency.

Figure 13: Compliance Matrix

10 PROJECT MANAGEMENT

10.1 Resources Estimates

Cost estimates are presented in Table 9. The schedule is present in Figure 14. The LE phasing divided in two phases, Detailed Design and Full Scale Development. The physical installation of the components or units will be done under WBS 9.2 Laser Enclosure Integration. Significant amount of resources support the Laser Enclosure activities are covered under the MRI laser proposal.

Personnel	**DD**	**FSD**	**DC**
AssoSci	94	144	0
SrSci	0	0	0
JunSci	0	0	0
Tech	16	16	0
SubMgr	8	8	0
ProjMgr	4	4	0
Subtotal	122	182	0
Procurements $	$ -	$ 6000	$ -
Total Effort (hrs)	**310**		
Total Procurements $	**$ 6000**		

Table 9: Cost Estimate

10.2 Schedule and Tasks

WBS	Task Name	Start	Finish
1	**NGAO Laser Enclosure (WBS 5.1 DD/FSD, WBS 9.2 DC)**	**Fri 10/1/10**	**Sat 2/21/15**
1.1	**Project Management & Reviews**	**Fri 10/1/10**	**Sat 2/1/14**
1.1.1	Project Start Date	Fri 10/1/10	Fri 10/1/10
1.1.2	LE Activities ready for Summit	Fri 12/21/12	Fri 12/21/12
1.1.3	Laser #2 Removal Decision	Fri 2/1/13	Fri 2/1/13
1.1.4	Laser #1 arrives at HQ	Wed 5/1/13	Wed 5/1/13
1.1.5	Pre-Telescope Readiness Review	Mon 7/1/13	Mon 7/1/13
2.0.20	K2 Laser goes Offline	Thu 8/1/13	Thu 8/1/13
1.1.7	Keck 2 Laser Removed Phase A	Fri 8/30/13	Fri 8/30/13
1.1.8	Operational Readiness Design Review	Fri 11/15/13	Fri 11/15/13
1.1.9	Laser #1 Shared Risk Semester 14A	Sat 2/1/14	Sat 2/1/14
1.2	**Detailed Design Phase**	**Fri 10/1/10**	**Fri 9/28/12**
1.2.1	DD Phase Management and Reporting	Fri 10/1/10	Wed 5/23/12
1.2.2	**Engineering Tasks**	**Fri 10/1/10**	**Mon 12/27/10**
1.2.2.1	**Opto-Mechanical**	**Fri 10/1/10**	**Mon 12/27/10**
1.2.2.1.1	Mounting Frame	Fri 10/1/10	Thu 10/28/10
1.2.2.1.2	LE Mods for Install and Servicing	Fri 10/29/10	Thu 11/25/10
1.2.2.1.3	LE for BTO Interface	Fri 11/26/10	Wed 12/22/10
1.2.2.1.4	LE for SYD Interface	Thu 12/23/10	Mon 12/27/10
1.2.2.2	**Infrastructure Support**	**Fri 10/1/10**	**Mon 11/1/10**
1.2.2.2.1	Electrical Power	Fri 10/1/10	Thu 10/14/10
1.2.2.2.2	Glycol Cooling Manifold	Fri 10/15/10	Mon 11/1/10
1.2.2.3	**Electronics**	**Fri 10/1/10**	**Thu 10/28/10**
1.2.2.3.1	Environmental: Temperature, Humidity, HEPA	Fri 10/1/10	Mon 10/18/10
1.2.2.3.2	Electronics Interface	Fri 10/1/10	Thu 10/28/10
1.2.3	**System Engineering Tasks**	**Tue 12/28/10**	**Fri 9/28/12**
1.3	**Full Scale Development Phase**	**Wed 5/23/12**	**Wed 4/23/14**
1.3.1	FSD Phase Management and Reporting	Wed 5/23/12	Wed 4/23/14
1.3.2	**Engineering Tasks**	**Wed 5/23/12**	**Thu 12/6/12**
1.3.2.1	**Opto-Mechanical**	**Wed 5/23/12**	**Thu 12/6/12**
1.3.2.2	**Infrastructure**	**Wed 5/23/12**	**Thu 6/7/12**
1.3.2.3	**Electronics**	**Wed 5/23/12**	**Mon 7/9/12**
1.3.3	**System Engineering Tasks**	**Thu 12/6/12**	**Fri 12/21/12**
1.4	**Delivery and Commissioning Phase**	**Fri 8/30/13**	**Sat 2/21/15**
1.4.1	DC Phase Management and Reporting	Fri 8/30/13	Sat 2/21/15
1.4.2	**Engineering Tasks**	**Fri 8/30/13**	**Thu 10/24/13**
1.4.2.1	**Opto-Mechanical**	**Fri 8/30/13**	**Fri 9/27/13**
1.4.2.2	**Infrastructure**	**Fri 9/27/13**	**Tue 10/8/13**
1.4.2.3	**Electronics**	**Tue 10/8/13**	**Thu 10/24/13**
1.4.3	**System Engineering Tasks**	**Thu 10/24/13**	**Fri 11/15/13**

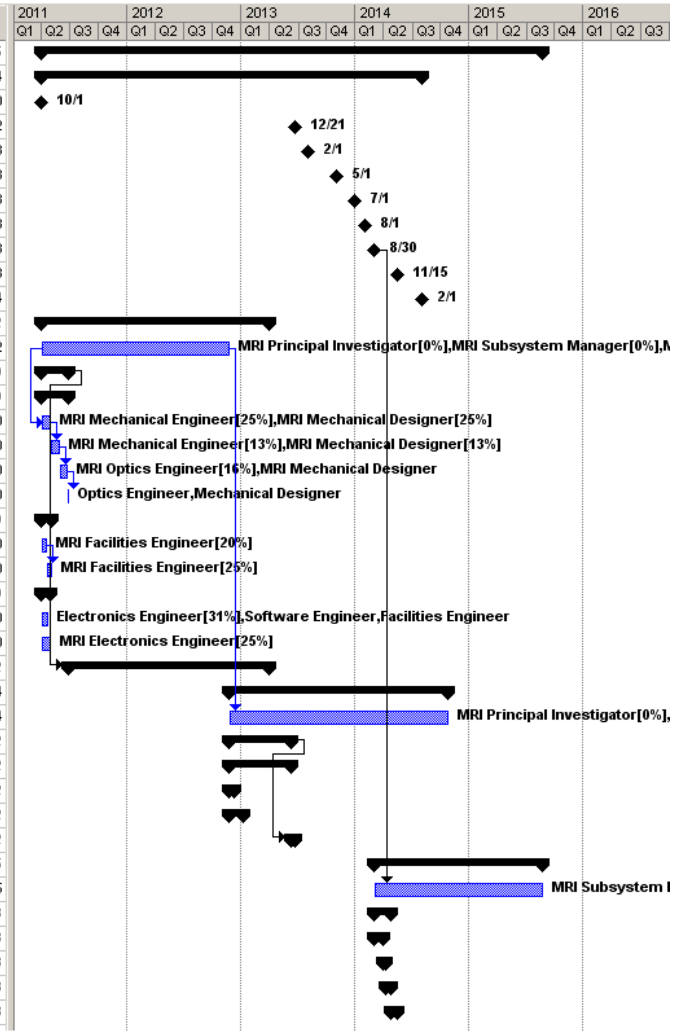

Figure 14: Project Schedule and Tasks

10.3 Risk and Risk Reduction Plan

A major risk that was brought up during the mini-review regarding the size of the laser systems has been put to rest. The current NGAO laser systems are sufficiently small that all three lasers will fit in the existing LE. One new risk arose based on the requirements from the laser manufacturer.

Table 10 shows individual risks within LE in accordance with KAON 510.

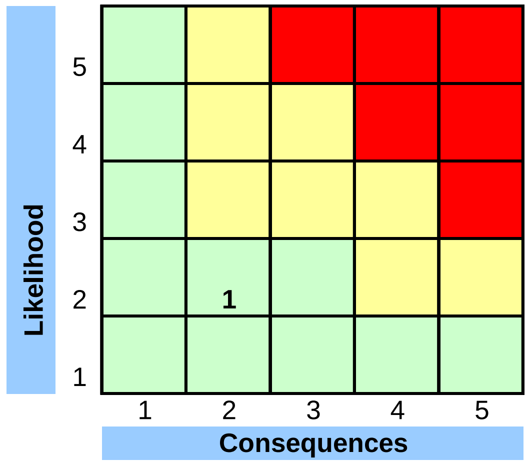

Table 10: Risk Matrix

#	Consequence	Likelihood	Description	Status	Mitigation
1	2	2	Laser System cooling	A design is in place to support this requirement; however, more study is needed to ensure there is no major impact to the telescope.	During DDR, the current design will be vetted to ensure it will not be detrimental to the telescope or observing.

Table 11: Risk Analysis

10.3.1 Laser System Cooling

The current lasers require 18°C at the laser heads in order for it to operate. Within the laser head, sufficient insulation is provided to ensure this heat is not an impact for the environment. However, 18°C glycol lines can be a problem and if not insulated properly emit heat into the dome. The current design of such a system is in the laser design document. During DDR, a more thorough investigation shall be made to ensure the system will be sufficiently insulated to not radiate heat into the dome and the LE.

11 PLANS FOR THE NEXT PHASE

In the Detailed Design phase, the designs listed in the deliverables will be completed with technical drawings to support the Full Scale Development Phase. Integration and Test Plans will also be provided to verify the fabricated designs.