LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

– LIGO –

CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SOP	LIGO-M010088-00-R	6/9/01

Standard Operating Procedure
LIGO 10-W Laser for the Interferometer Operating in the Caltech 40 Meter Laboratory

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1 Purpose and Scope

This Document is the Standard Operating Procedure (SOP) for the LIGO 10-Watt Pre-Stabilized Laser (PSL) for the Caltech 40 Meter Interferometer (40m IFO) when it is operating in the Caltech 40 Meter Laboratory. It is designed to ensure the safety of all personnel and equipment in and around the area where the 40m LIGO 10-W Laser is operating. Its role within the overall laser safety plan is described in LIGO-M960001-B-P, *LIGO Laser Safety Program*.

This SOP contains the essential procedures required for the safe operation of the 40m LIGO 10-W Laser and must be approved by both the LIGO 40m Laser Safety Officers and the Caltech Site Safety Officer.

2 Caltech 40 Meter Laboratory Layout

There will be a single LIGO 10-W Laser in the 40 Meter Laboratory, for the 40m IFO. The laser, the ancillary optical components that comprise the Pre-stabilized Laser (PSL) and some of the Input Optics detector subsystem (IOO) components, are mounted on a large (10 ft. x 6 ft. x 1 ft.) optical table. The optical table is surrounded by the IOO/PSL Optical Table laser safety enclosure (refered to in this document as the *PSL enclosure*), similar to those at the LIGO Observatory sites. The PSL enclosure contains several laser safety windows (tested to stand the direct impact of the 10-W laser for at least 8 hours before there's any leakage through the other side). However, the enclosure is *not* surrounded by a Laser Area Enclosure as at the sites. The absence of a separate Laser Area Enclosure means that the 40m PSL cannot be operated in the Laser Safe Condition (see section 5 below), in contrast to the Observatory sites (see, for example, LIGO-M990151-B-L for the LLO site SOP).

The location of the laser, PSL optics, and optical table and enclosure, in the 40m lab is shown schematically in Figure 1 and Figure 2. It is labeled *PSL*. The laser, all input (to the vacuum envelope) and output beams, and the entire vacuum envelope, reside in the IFO Hall. The PSL enclosure is in the *vertex area*, shown in Figure 2. The vacuum envelope extends to the *South arm* and the *East arm*. The vacuum envelope containing the laser beams is shown as thick red lines in Figure 1. Normal entrance to the IFO Hall is through (a) the *entrance hallway*, containing cleanroom booties, and (b) the *control room*; both entrances are in the vertex area. There are two emergency exits, one at the end of the South arm and one at the end of the East arm. The entire 40m IFO Hall constitutes the *Nominal Hazard Zone* (*NHZ*). The 40m control room and north and south annex work areas are not part of the NHZ.

As described below, all entrances to the 40 Meter Laboratory and to the IFO hall have appropriate Laser Hazard Warning signs. In the Laser Hazard states (described below), illuminated signs are energized outside of each entrance to the IFO Hall. Laser Emergency OFF switches are located at all entrances to the IFO hall and at strategic places near the PSL enclosure, as shown in Figure 1 and Figure 2.

After conditioning by the PSL optics, the beam propagates through the IOO optical components mounted on the IOO/PSL Optical Table, then exits through an aperture in the IOO/PSL Optical Table Enclosure. The beam then propagates through a beam tube, then through an optical

window into the Output Optic vacuum Chamber (OOC) adjacent to the IOO/PSL Optical Table, to the optical components mounted inside the vacuum envelope. In the vacuum envelope, the main laser beam enters the 12 meter suspended optic mode cleaner in the Input Optic chamber (IOC). Following that, it enters a fixed-mount reflective mode matching telescope in the IOC. It then propagates into the beamsplitter chamber (BSC) and propagates through the Core Optics (COC) optical components, and therefore throughout the entire vacuum enclosure, including the south arm and east arm. For interferometer sensing and control, laser radiation exits the vacuum envelope through various windows in the vacuum chambers These output beams are indicated in Figure 1 and Figure 2.

In addition to the main LIGO 10-W Laser in the 40 Meter Laboratory, there are several (on the order of 10) Class IIIa He:Ne lasers operating at 635 nm (red) at less than 5 mW, used as optical levers for sensing the alignment of the suspended optics in the IFO. These are indicated in Figure 1 and Figure 2.

3 Laser Description

The LIGO 10-W Laser is a Class IV Nd3+:YAG laser. It is a model 126 MOPA laser system manufactured by Lightwave Electronics Corp. The output from this laser is in the near-infrared region of the electromagnetic spectrum and is therefore not visible to the human eye. This laser emits radiation from two apertures: the main output beam and a sample beam. The relevant operating parameters for the LIGO 10-Watt Laser are:

- MAIN BEAM
    - 1064 nm wavelength
    - 12 W max. power output
    - continuous wave output
    - 6.1 kW/cm^2 intensity at output aperture
- SAMPLE BEAM
    - 1064 nm wavelength
    - 70 mW max. power output
    - continuous wave output
    - 36 W/cm^2 intensity at output aperture

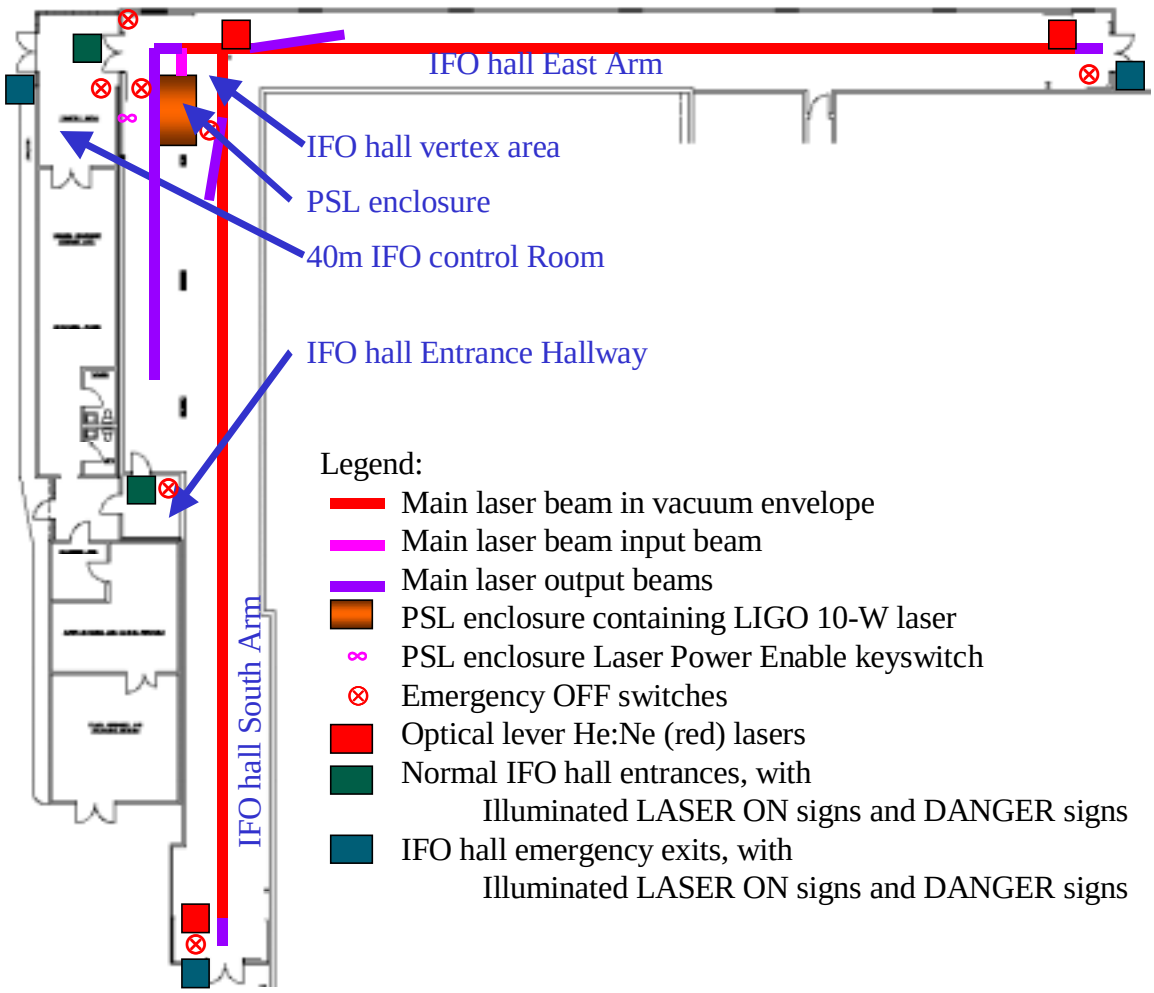

Figure 1: Layout of the 40m IFO Laboratory showing the location of the LIGO 10-W lasers.

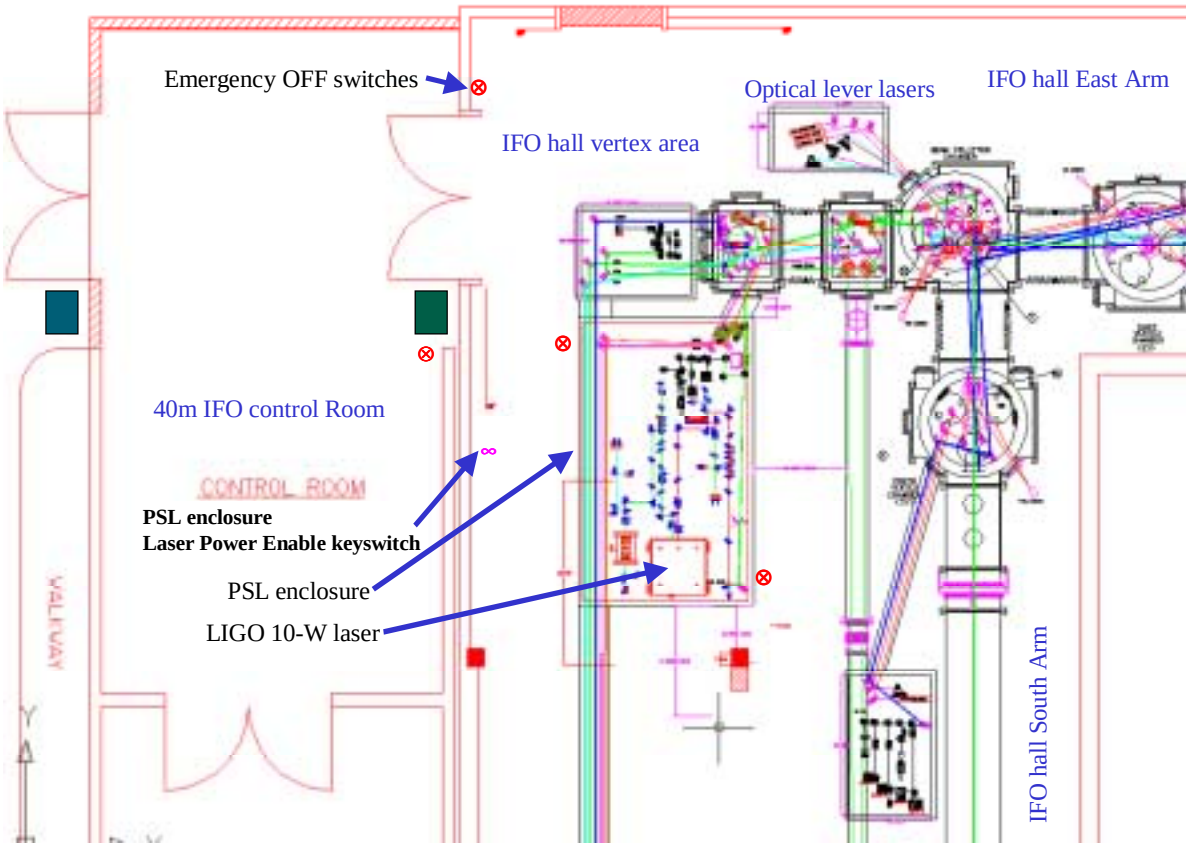

Figure 2: The IFO hall vertex area of the 40m IFO Laboratory showing the location of the LIGO 10-W lasers.

4 HAZARDS

A Class IV laser is a hazard to the eye or skin from the direct beam, may be a hazard from a diffuse reflection, and may also be a fire hazard. Infrared lasers such as the LIGO 10-W Laser pose an additional hazard because the output radiation is not visible to the unaided human eye.

There are two potentially dangerous output beams from the LIGO 10-W Laser as described in Section , above.

There are approximately 10 He:Ne lasers used at the 40m IFO as optical levers. They are class IIIa, < 5mW laser diodes, emitting 635 nm beams. The typical 1/4 second blink reflex will protect your eyes from a brief direct or spectral reflection. Direct beam exposures of approximately 10 seconds or longer could cause eye damage.

5 CONTROLS

For the purpose of laser safety, three conditions have been defined for the 40m IFO hall: LASER SAFE, LASER HAZARD, and LASER HAZARD - DOORS OPEN. These conditions are defined solely on the basis of the PSL enclosure power enable keyswitch (“ON” or “OFF”), and the condition of the PSL enclosure doors.

The LASER HAZARD condition shall exist any time the PSL enclosure power enable keyswitch is "ON", so that power to the 40m IFO LIGO 10-W Laser is enabled and the laser is capable of operating and emitting a beam of laser light.

The LASER HAZARD - DOORS OPEN condition shall exist any time the PSL enclosure power enable keyswitch is "ON", and one or more of the PSL enclosure doors is/are open. This condition shall exist only when trained laser personnel are actively working at the PSL laser table.

The LASER SAFE condition shall exist only when the power to the 40m IFO LIGO 10-W Laser is disabled, so that the laser is incapable of being energized.

5.1 Status Controls

The procedure for transitioning from the LASER SAFE to the LASER HAZARD condition is in *Procedure for Transition to the LASER HAZARD Condition* (Appendix C). The procedure for transitioning from the LASER HAZARD to the LASER SAFE condition is in *Procedure for Transition to the LASER SAFE Condition* (Appendix D). The procedure for transitioning from the LASER HAZARD to and from the LASER HAZARD - DOORS OPEN condition is in *Procedure for Transition to the LASER HAZARD - DOORS OPEN Condition* (Appendix E). These procedures include the verification that the automated illumination of the laser warning signs during transition to the LASER HAZARD condition is operating correctly.

The PSL Enclosure power enable keyswitch is locked in the “off” position when transitioning to the LASER SAFE condition. This is described in more detail in the procedures in the Appendices.

5.2 Emergency OFF Switches

Emergency OFF switches are located at all entrances and emergency exits to the IFO hall, and in strategic places on and near the PSL enclosure, as indicated in Figure 1 and Figure 2. Activation of any Emergency OFF switch shuts down the power to the laser.

5.3 Access Controls

The designated Nominal Hazard Zone (NHZ) includes all of the IFO hall.

The two normal entrances to the IFO hall from the 40 Meter Laboratory are at the entrance hall-way and the control room. At these two locations, illuminated signs reading “LASER ON” are energized automatically when the laser power is enabled. Laser safety warning signs with the message, “DANGER VISIBLE AND/OR INVISIBLE LASER RADIATION - AVOID EYE OR

SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION. EYE PROTECTION REQUIRED" are mounted nearby.

The two outside access doors to the IFO hall at the South and East ends, and the double doors leading from the outside into the 40m IFO control room, are for emergency egress only. At these two locations, illuminated signs reading "LASER ON" are energized automatically when the laser power is enabled. Laser safety warning signs with the message, "LASER HAZARD - AUTHORIZED LASER PERSONNEL ONLY." are mounted nearby.

Access to the 40m IFO hall is strictly controlled when the LASER HAZARD conditions exists. At these times, only Registered Laser Personnel are authorized to enter the IFO hall without an escort. The names of all Registered Laser Personnel are posted near the illuminated warning signs at the entrance of the IFO hall, and near the PSL Enclosure. Names can be added to the list only by the sponsor of this SOP or by the Caltech LIGO Laser Safety Officer and only after training which satisfies the requirements detailed in LIGO-M960001-B-P, *LIGO Laser Safety Program.*

5.4 Electrical Controls

In order for the laser to be energized, (a) the PSL isolation transformer must be powered; (b) the PSL power circuit breaker must be enabled; (c) the PSL enclosure circuit breaker must be enabled; (d) the PSL enclosure power enable keyswitch on the wall facing the west side of the PSL enclosure must be in the "ON" position; (e) the laser power supply in the PSL rack must be switched "ON".

Emergency OFF switches are located at all entrances to the IFO hall, and at the NW and SE corners of the PSL enclosure. The laser power enable keyswitch is located near the NW corner of the IFO Hall, across from the west side of the PSL enclosure. The LASER SAFE condition exists only when that keyswitch is in the "OFF" position.

The PSL enclosure doors have magnetic contacts that sense when the doors are open or closed. In the LASER HAZARD condition, all doors are closed. If a door is opened, an alarm will sound and the laser interlock will break, and the laser will trip off.

In the LASER HAZARD - DOORS OPEN condition, it is necessary for the doors to be open while the laser is on, in order to permit work on the laser optics on the table. Two switches on the laser enclosure exist for this purpose: one disables the door alarm, and the other disables the laser interlock trip.

All control and monitoring functions for the LIGO 10-Watt Laser are accessed via the laser power supply (labeled 126 MOPA) located in the rack next to the PSL optics table. Most control and monitoring functions can be remotely activated via the PSL CDS interface, once the laser has been energized as described above.

5.5 Beam Controls

A button on the front panel of the laser power supply activates a solenoid which opens and closes a shutter inside the laser head. These functions can be remotely controlled via the PSL CDS

interface. From the standpoint of laser safety, the laser is considered to be activated even when the shutter is closed and/or the laser is in the standby mode.

5.6 Eye Protection

Required protective eyewear for the LIGO 10-W Laser must have an optical density (OD) of greater than 5.0 for 1064 nm wavelength radiation.

6 OPERATING PROCEDURES

1. No one should energize or work with or near the 40m IFO LIGO 10-W Laser unless authorized to do so. All persons operating the laser must have completed laser safety training and be registered with the LIGO Laboratory as specified in LIGO-M960001-B-P. All persons operating the laser must be familiar with all operating procedures, including emergency service procedures, emergency phone numbers, etc.
2. The procedure described in *Procedure for Transition to the LASER HAZARD Condition* (Appendix C) must have been executed, including the illumination of all Laser warning signs, before the 40m IFO LIGO 10-W Laser is operated.
3. When the LASER HAZARD condition exist, all persons entering or already present in the 40m IFO hall are required to wear eye protection as described in Section 5.6, above, before entering and at all times while working within the 40m IFO hall (NHZ).
4. The PSL enclosure doors shall remain closed at all times when the LASER HAZARD condition exists, except when authorized personnel are actively working with equipment on the PSL optical table. If the laser has been operating unattended, upon entering the Responsible Laser Operator must scan the vicinity of the optical table for stray beams, and note this in the Operator's Log (Appendix A).
5. When it is necessary to have the doors open for work on the PSL table while the laser is capable of being energized, the procedure described in *Procedure for Transition to the LASER HAZARD - DOORS OPEN Condition* (Appendix E) must be followed. The work shall be completed, and the transition back to LASER HAZARD shall be made, promptly.
6. Any time one or more people will be working on equipment on the PSL optical table, or the laser will be running unattended, ONE person shall be designated the "Responsible Laser Operator." The name of the Responsible Laser Operator shall be posted near the PSL Enclosure laser warning sign.
7. The Responsible Laser Operator shall coordinate activities on or in the vicinity of the laser optical table. Multiple independent activities involving manipulation of the laser beams shall not occur simultaneously. Any time the laser beams will be manipulated, e.g. by inserting, removing, or adjusting optical components, persons not directly participating in the beam manipulation activity will move to a safe location until the activity is completed and normal operating conditions have been restored following scans for stray beams, as described below.

8. Before and during insertion or removal of any optical component, the power of all affected laser beams shall be reduced to the lowest possible practical level, and any laser beams exiting the PSL enclosure shall be blocked (unless the presence of the beam in the IFO vacuum envelope is required).

9. All persons manipulating the laser beams, e.g., by placing objects such as mirrors, lenses, power meters, or beam dumps, into or near the laser beam paths, must remove all jewelry such as wrist watches and rings.

10. Immediately after inserting, removing, or making significant adjustments to any optical component, the vicinity of the optical table shall be scanned with an infrared viewer or other suitable beam-finding device to ensure that all stray beams are dumped, and a record of this activity must be noted and signed for in the log (Appendix B).

11. Scattering of laser light shall be kept to a minimum at all times by maintaining proper alignment of optics, utilization of beam dumps, and ensuring that optics are securely fastened.

12. Each time the laser will be left running unattended, the vicinity of the optical table shall be scanned for stray beams immediately prior to closing the PSL Enclosure doors, and note this in the Operator's Log (Appendix A). The "unattended" status of the laser shall be posted near the name of the Responsible Laser Operator near the PSL Enclosure laser warning sign.

13. When the laser is no longer required to be energized, the procedure described in *Procedure for Transition to the LASER SAFE Condition* (Appendix D) must be executed, and the "laser safe" status of the laser shall be posted near the name of the Responsible Laser Operator near the PSL Enclosure laser warning sign. At the completion of that transition, the Laser Power Enable key shall be in its proper place in the 40m control room. If the laser is to remain off for any extended period of time, the Responsible Laser Operator should place the key in a secure place.

It is the responsibility of each person working within the 40m IFO hall (NHZ) to ensure that LIGO standards for safe laser operation are being followed at all times, by all persons present. Watch out for the safety of all persons present.

APPENDIX A

40m IFO LIGO 10-W Laser Operator's Log

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

Name _____ Date _____

Entrance Scan O Time _____ / Exit Scan O Time _____

APPENDIX B

LIGO 10-W Laser Configuration Log

(Brief description of change to table configuration)

Scanned for stray beams:

Name _____ Date/Time: _____

(Brief description of change to table configuration)

Scanned for stray beams:

Name _____ Date/Time: _____

(Brief description of change to table configuration)

Scanned for stray beams:

Name _____ Date/Time: _____

(Brief description of change to table configuration)

Scanned for stray beams:

Name _____ Date/Time: _____

APPENDIX C

Transition to the 40m IFO LASER HAZARD Condition Procedure

Date: _____ Lead Operator:_____

Aided By: _____

_____

The purpose of this procedure is to make the transition from the LASER SAFE to the LASER HAZARD condition as described in the document *Standard Operating Procedure: LIGO 10-W Laser for the Interferometer Operating in the Caltech 40 Meter Laboratory*, LIGO-M010088.

Initial in the space provided next to the number for each step in the procedure as it is completed.

_____ 1. Obtain written or verbal approval for the transition from the Responsible Laser Operator on duty.

_____ 2. Inform all personnel in the 40m IFO hall and control room of the intent to transition to the **LASER HAZARD** condition, and ensure that all personnel in the 40m IFO hall are wearing approved laser safety glasses and are in compliance with the Standard Operating Procedures (SOP) for the LIGO 10-W Laser in the Caltech 40m Laboratory.

_____ 3. Obtain clearance from the control room or the Responsible Laser Operator on duty to energize the LIGO 10-W Laser power supply.

_____ 4. Ensure that the PSL enclosure power enable keyswitch is set to “OFF”, and that all Emergency OFF switches have been reset.

_____ 5. Ensure that the power supply for the LIFO 10-W Laser is “OFF”.

_____ 6. Insert the key into the PSL enclosure power enable keyswitch, and switch to “ON”.

_____ 7. Ensure that all LASER ON signs are illuminated.

_____ 8. Energize the LIGO 10-W Laser power supply.

_____ 9. Scan for stray beams, and note the transition on the Operator’s Log (Appendix A).

_____ 10. Inform all personnel in the 40m IFO hall and control room of the completion of the transition to the **LASER HAZARD** condition.

Comments/Information

Note any unusual conditions and inform appropriate personnel.

_____

_____

_____

_____

_____

Acknowledge Task
Completion by _____Date: _____ Time: _____

(Signature/Title)

APPENDIX D

Transition to the 40m IFO Laser SAFE Condition Procedure

Date: _____ Lead Operator:_____

Aided By: _____

_____

The purpose of this procedure is to make the transition from the LASER HAZARD to the LASER SAFE condition as described in the document *Standard Operating Procedure: LIGO 10-W Laser for the Interferometer Operating in the Caltech 40 Meter Laboratory*, LIGO-M010088.

Initial in the space provided next to the number for each step in the procedure as it is completed.

_____ 1. Obtain written or verbal approval for the transition from the Responsible Laser Operator on duty.

_____ 2. Obtain clearance from the control room or the Responsible Laser Operator on duty to turn off the LIGO 10-W Laser power supply.

_____ 3. Install beam dump in the 40m IFO PSL optical table enclosure output beam (inside the enclosure).

_____ 4. Turn off the LIGO 10-W Laser power supply.

_____ 5. Move the Laser Power Enable keyswitch to the “off” position. If the laser is to remain off for any extended period of time, the Responsible Laser Operator shall place the key in a secure place.

_____ 6. Ensure that all LASER ON signs are no longer illuminated.

_____ 7. Inform all personnel in the 40m IFO hall and control room of the completion of the transition to the **LASER SAFE** condition. Note the transition on the Operator’s Log (Appendix A).

Comments/Information

Note any unusual conditions and inform appropriate personnel.

_____

_____

_____

_____

_____

Acknowledge Task
Completion by _____Date: _____ Time: _____

(Signature/Title)

APPENDIX E

Transition to the 40m IFO Laser HAZARD - DOORS OPEN Condition Procedure

Date: _____ Lead Operator:_____

Aided By: _____

_____

The purpose of this procedure is to make the transition from the LASER HAZARD to the LASER HAZARD - DOORS OPEN condition (and back) as described in the document *Standard Operating Procedure: LIGO 10-W Laser for the Interferometer Operating in the Caltech 40 Meter Laboratory*, LIGO-M010088.

Initial in the space provided next to the number for each step in the procedure as it is completed.

_____ 1. Obtain written or verbal approval for the transition from the Responsible Laser Operator on duty.

_____ 2. Obtain clearance from the control room or the Responsible Laser Operator on duty to open the PSL Enclosure doors.

_____ 3. Notify all personnel present of the transition, and ensure that all persons not directly participating in the beam manipulation activity move to a safe location until the activity is completed and normal operating conditions have been restored.

_____ 4. Disable the enclosure door alarm and disable the enclosure door laser interlock trip.

_____ 5. Open the enclosure door(s), scan for stray beams, and note the transition on the Operator's Log (Appendix A).

_____ 6. Perform all the required on-table activities in an efficient and timely manner, with all due concern for the safety of all persons present.

_____ 7. Upon completion of the on-table activities, scan for stray beams and close all doors.

_____ 8. Ensure that all doors are closed completely (all door lights are off), then re-enable the enclosure door alarm and laser interlock trip.

_____ 9. Inform all personnel in the 40m IFO hall and control room of the completion of the transition to the **LASER HAZARD** condition. Note the transition on the Operator's Log (Appendix A).

Comments/Information

Note any unusual conditions and inform appropriate personnel.

_____

_____

_____

_____

_____

Acknowledge Task
Completion by _____Date: _____ Time: _____

(Signature/Title)