LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-M1000129-v2 *Advanced LIGO* 04/23/2010

Standard Operating Procedure for the Phase Camera 500mW NPRO Laser at the Caltech 40m Laboratory

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Distribution of this document:
Lasers and Optics

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LIGO Safety Officer

I. Introduction

This document is the Standard Operating Procedure (SOP) for the 500mW NPRO laser for the phase camera experiment, known hereafter as the 500mW PC Laser, at the Caltech 40M Interferometer (40m IFO). The NPRO VGL lasers is:

- a commercially available ***Innolight Mephisto 500mW Nd:YAG laser***

The laser is used to investigate new phase-camera designs for Advanced LIGO.

A. Location/Diagrams of Lasers in Caltech 40 Meter Laboratory Layout

The floor plan of the 40M Lab is shown in Figure 1. The whole IFO hall is the Nominal Hazard Zone (NHZ). The control room, north/south annex work areas are non-hazard areas. All entrances to the 40M Lab and to the IFO hall have appropriate Laser Hazard Warning signs.

In the Laser Hazard states (described below), signs are energized out side of each entrance to the IFO Hall. Laser Emergency OFF switches are located at all entrances to the IFO hall and near the PSL enclosure, as shown In Figure 1 and Figure 2.

The 500mW PC laser is located on the Symmetric Port (SP) table next to the PSL enclosure as depicted in Figure 1. Note that the name for this table is historical, but it no longer houses the symmetric port of the main 40m interferometer.

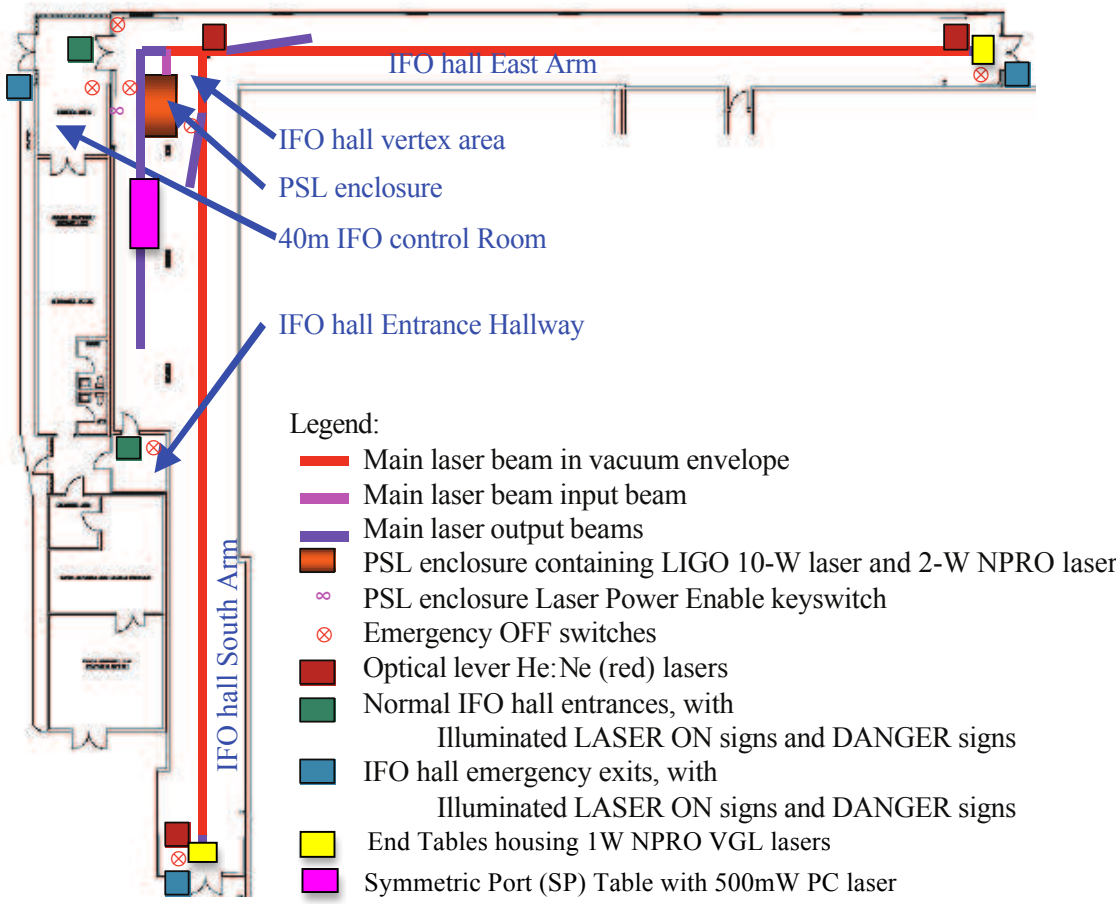

Figure 1. Layout of the 40M Lab showing the location of the 500mW PC laser.

The location of the 500mW PC Laser on the SP Table is shown in Figure 2. The SP table is fully enclosed by a high black aluminium shield. Aluminium lids that are also in place when the table is not in immediate use.

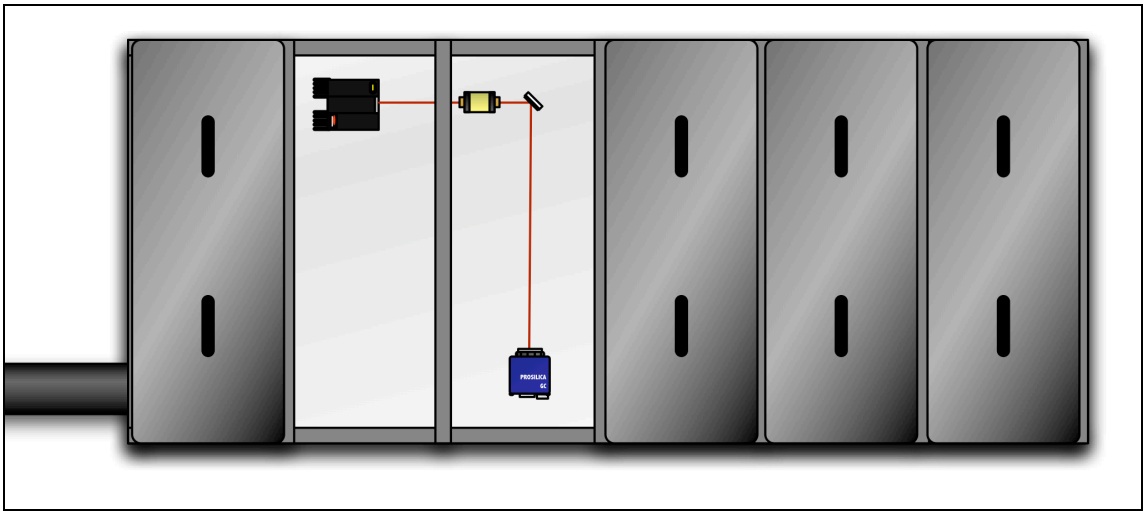

Figure 2. The location of the 500mW PClaser NPRO on the SP table. Some of the black aluminium lids are shown, as is the connecting tube to the PSL table.

B1. Description of each laser

The parameters of the 500mW PC Laser are shown in Table.1.

Parameter	500mW Innolight Laser
Laser Classification	Class 4
Output Wavelength	1064nm (near IR, invisible)
Output Power (nominal)	500 mW
Mode of Operation	continuous wave
Beam Radius	~250 μm
Full Angle Beam Divergence	~ 2 mrad

Table 1. The characteristics of the 500mW PC Laser

B2. Other lasers in the 40m

The lab also contains additional lasers:

1. LIGO 10W PSL Laser (1064nm infrared) on the PSL table. See LIGO M010088-02-R for the SOP
2. LIGO 2W PSL Laser (1064nm infrared) on the PSL table. See LIGO M1000099-v1 for the SOP
3. LIGO 1W and 700mW VGL Lasers (1064nm infrared on the End Tables). See M1000101-v4 for the SOP
4. Class 3R He:Ne Lasers (635nm red) at less than 5mW used for optical levers.

C. Purpose and scope (application of beams)

The 1064nmm PC laser is used to test new phase camera designs that use a modulated CCD instead of a scanning galvo system. The laser will be split into two beams that will be frequency shifted and recombined such that there is an acoustic beat between them. This will take place on the SP table in an area approximately 1m x 1m.

II. Hazards

A. Identification of hazards

Beams

A 500mW NPRO laser is an infrared laser and is therefore not visible to the naked eye. The output power of this laser is such that it is a hazard to the eyes and skin.

In most instances on the table, the beam size on the table is of the order of 1-2 mm diameter. According to the Table 7 in the American National Standard Z136.1-2007 the MPE for Skin Exposure of 1064nm radiation for ~1s duration is about 5.5 J/cm^2. Exposure will be less than the MPE in this circumstance if the beam power is attenuated to less than

90mW. In instances where one is working near the focus of a beam on the table (approximately 50 microns diameter), exposure will be less than the MPE if the beam power is attenuated to ~200μW. In practice, one should always align using the minimum practical amount of power necessary to accomplish the task.

III. Controls

A. Access controls

The designated Nominal Hazard Zone (NHZ) includes the entire IFO hall. The two normal entrances to the IFO hall from the 40M Lab are at the entrance hallway and the control room. At these two locations, “LASER ON” and “LASER HAZARD” signs are indicated.

Access to the 40m IFO Hall is strictly controlled when the illuminated laser exists. **At all times, even if the laser signs are not illuminated,** only Registered Laser Personnel are authorized to enter the IFO hall without an escort.

The beam height used in any experiments shall be such that it is not at eye level for a person that is seated or standing. The nominal beam height on the End tables is 4” as measured from the table surface. All stools inside the lab should seat individual’s eyes well above this level.

B. Beam controls

The NPRO lasers are equipped with a mechanical shutter that blocks the output of each laser. The mechanical shutter is manual and can be closed by pressing on it with a finger. When a laser is not in use, the mechanical shutter is to remain closed. Beam dumps shall be used to block beams rejected by polarizers and unintended reflections — for example those from the windows of photodetectors. High power regions of the beam will also be guarded by black anodized aluminum sheet (e.g. from Thorlabs).

There is a 1ft high black anodized aluminium shield around the perimeter of the table that encloses the area and prevents beams from leaving the table. The shield has a lid that, in conjunction with the shield, completely encloses the end-table. The lid is in place at all times that the table is unattended.

C. Electrical controls

The power supplies for the PC lasers has an LED displays and lights that indicate the laser is in ON, as shown above

The laser is connected to dedicated “Kill”/emergency shut-down circuits that is located below the table at knee height, as shown below.

D. Eye protection

Laser safety eyewear with an optical density of at least +05 should be worn **at all times** in the 40m IFO Hall, **even when the laser warning light is not illuminated**. The only exception to this is if a “Laser Safe Mode” sign has been posted at the entry doors by the 40m Safety Officer stating that eyewear is not required.

The OD+05 is required for the 10W laser covered by M010088-02-R “*Standard Operating Procedure LIGO 10-W Laser for the Interferometer Operating in the Caltech 40 Meter Laboratory*”.

The laser safety eyewear is located just outside of the IFO Hall Entrance Hallway. ALL eyewear stored in this area shall meet or exceed the OD05 requirement at 1064 nm.

IV. Operating Procedures

A. Lab Entry Procedure

Prior to entering the Lab, the status of the laser should be checked by looking at the illuminated laser status sign located outside of the entrance. Laser safety eyewear is located outside of the entrance hallway to the IFO hall and should be donned at this point.

There is an enclosure box around the laser table, however one should always approach the table with caution. The laser will be operating at full power nearly continuously.

If, for whatever reason, a person feels unsafe, he/she should engage the interlock switch located on the PSL enclosure corner. There is a local kill-switch button for the PC Laser located on the SP table as described in Section III-C.

Mandatory IR entry-scan are required with the start of any laser related work in the 40m.

All jewelry, watches, rings, bracelets, etc should be removed at all times when working with the laser. Loose clothing and hair should be tied back when working with the laser to prevent it from falling into the beam path.

At least one experienced laser operator is required when working with a high power beam. Laser related work should be communicated and scheduled such that one is not working alone with the high power beam.

B. Personnel Protection requirements

Anyone within in the NHZ must wear laser safety eyewear described in Section III. D.

The protective shields around the SP table shall be in place during operation and shall not be removed or interfered with unless the NPRO laser is completely powered down.

C. Target Area

The target area of the 1064nm NPRO laser is within the confines of the SP table, as illustrated by the pink region in Figure 2. At no time should the IR beam leave this region.

D. Powering Up Procedure

If the laser is powered off, make sure that the mechanical shutter is closed and that no one is in the direct line of the beam. Turning on the laser is a single step process:

Turn on the laser at the power supply.

To enable the power supply, turn the key switch located on power supply front panel to ON. If others are present, announce that you are about to power up the laser and check that they are wearing the appropriate laser safety eyewear. The laser is then activated by pressing the “laser ON” button on the power supply front panel and turning up the drive current.

E. Shutdown Procedure

To power off the laser, turn down the drive current and press the “laser OFF/Standby” button on the front panel of the power supply. Close the mechanical shutter. Remove the key from its slot.

Mandatory IR exit- scan is required with leaving your experimental set-up unattended for lunch or finishing it for the day. If stray beams are found on the table, remedy the situation by the appropriate use of beam dumps or other suitable measures.

If the laser does not need to be left on for long-term monitoring, close the laser shutter and switch off the laser.

F. Alignment Procedures

Proper alignment of optical components helps reduce the dangers present when working with lasers. When placing components in the main beam, use the minimum practical amount of power necessary to accomplish the task. It is recommended that the power control located near the output of the laser be used to reduce the laser power. If the power control — consisting of a half waveplate and polarizing beamsplitter cube — is not installed reduce the laser’s pump diode current with the laser power supply. A temporary beam block should be installed at the end of the beam path. It can be removed at the end of the alignment task. After completion of the alignment, a scan of the optical table shall be made with an infrared viewer to check for the presence of either undumped beams or stray beams. Infrared viewing cards are also provided to aid in aligning components.

At no stage should personnel bring their eye level to the beam height or place their eyes in the direct line of the beam. Should any alignment require viewing along the direct beam path, a CCD camera is to be used.

G. General Standard Operating Procedures:

1) When the laser is operating within the Laser Nominal Hazard Zone (NHZ), the laser warning sign must be energized and all persons entering the NHZ are required to wear eye protection as described in Section III, Controls, before entering and at all times while working within the NHZ.

2) Prior to powering up the laser, the Responsible Laser Operator (the person actively in charge of the laser) shall ensure that all persons in the NHZ are aware of his/her intent to power up the laser and that they are in compliance with all laser safety requirements, eye protection in particular.

3) When work is required inside the End-Table laser enclosure, the senior researcher operating on the table automatically becomes the Responsible Laser Operator.

4) 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 only occur simultaneously when the Responsible Laser Operator deems it safe to do so.

5) Any time the laser will be running unattended, the control is under the Control Room Jurisdiction. For R & D labs, the LSO must verify that appropriate safeguards are in place before unattended laser operation can start.

6) All eye wear must be compatible for all laser systems running concurrently. When

in doubt, consult the Laser Safety Officer. When multiple lasers are being used, the governing SOPs must consider safety compatibility.

7) 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.

8) Before and during insertion or removal of any optical component, the power of the affected laser beams shall be reduced to the lowest working power setting or be blocked upstream by an appropriate device, such as a ceramic wand.

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 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 optical table shall be scanned to ensure that all stray beams are dumped.

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) A buddy system should be used when working with the laser, such that relatively inexperienced laser personnel are accompanied by experienced laser personnel.

NOTE: *If a laser beam with power in excess of 2 mW is found (reported by any observer), leaving the optics table, the laser will be shut down by the LSO and will remain "OFF" until start-up authorization is received.*

It is the responsibility of each person working within the Laser Nominal Hazard Zone (NHZ) to ensure that LIGO and ANSI Z136.1 standards for safe laser operation are being followed at all times

V. Training Requirements

A. Laser Safety Orientation Requirements (Basic Laser Training)

Any intended laser operator should have under gone the basic laser safety instruction as required by the LIGO Laser Safety Program.

B. Laser-specific safety training requirements

In addition, the intended laser operator should receive a walk around of the 40M Lab from the Registered Laser Personnel. The walk around shall give an up-to-date description of the 40M Lab and any particular hazards present at that time. They shall also be receive a demonstration of the correct operation of the NPRO lasers as described in Section IV: Operating Procedures in this document.

Upon completion of these requirements, the laser operator's name will be added to the list of Registered Laser Personnel list posted outside the Lab. This addition is done only by the authors of this SOP or by the Caltech LIGO Laser Safety Officer.

C. Training maintenance and repair personnel

No internal maintenance of this laser shall take place on the SP-Table. Internal maintenance and repair of this laser will require a separate SOP.

VI. Responsibilities

A. Cognate Laser System Engineers contacts

Contact name: Aidan Brooks.

Daytime phone number: (626) 395-2005

Contact name: Steve Vass

Daytime phone number: (626) 395-4219

Contact name: Rana Adhikari

Daytime phone number: (626) 395-8709

B. Supervisory (emergency contact)

Contact name: Rana Adhikari

Daytime phone number: (626) 318 0149

VII. Miscellaneous

A. Rules for visitors during laser operation

Visitors must be accompanied by one or more Registered Laser Personnel. Visitors are not permitted to interact with the laser system.

B. Procedures in case of accident

As per Section VII in M960001 “LIGO LASER SAFETY PROGRAM”, the following steps must be taken in case of an accident or incident:

If a laser worker suspects that they may have been exposed to laser irradiation, the following steps should be taken, listed in order of priority:

1. Notify those in the immediate area and turn off the laser

2. Report to the applicable Medical Group for an eye and other medical exam as necessary.

3. Notify supervisor and Observatory/site or facility LSO as soon as possible.

4. The responsible LSO notifies the LIGO Deputy Director and the LIGO Safety Officer immediately. The LIGO Deputy Director will also notify the Caltech or MIT Safety office.

The LSO will investigate any suspected personnel exposure to excessive levels of laser irradiation and file a LIGO Incident Report form (Appendix A) within two days of the incident. A copy of the Incident Report form will also be maintained in the applicable personnel file.

(ii) A stray or errant laser beam is also considered a reportable laser incident

and any measurable stray/errant beam must be corrected or eliminated. The Directorate has established a stray/errant beam power threshold of 2mW (ref. LIGO technical document, T080153):

- If the stray/errant beam power is equal to or exceeds the threshold power, all related laser operations will be shut down and the Directorate contacted to determine the plan for resumption of operations.
- If the stray/errant beam power level is below the threshold, the incident is reported, and the operation may continue after the stray/errant beam is eliminated.

C. Other

- Emergency Procedures

Depending on the nature of the emergency the laser operator should activate the panic button, and then remove themselves from the Lab and dial 5000. The Caltech Emergency Response Guide is posted near every telephone in the 40M Lab and on the door to the 40M Lab.

-- Medical Emergency

Follow the instructions listed in the Caltech Emergency Response Guide. Any personal injury should be reported to your supervisor at the first available opportunity. If in doubt, call 5000.

-- Evacuation Procedure

There are four exits from the 40M Lab. One is located in front of the IFO hall entrance hallway. Another is located at the control room. The others are at each end of the arms. If evacuation of the 40M Lab is called for, exit from either of them. In the case of a small fire, the fire extinguishers in the 40M Lab are located at the entrance hallway and near the each emergency exits. Each of the fire extinguishers is an ABC dry chemical type, meaning that it is suitable for fires involving trash, wood, paper, liquids and electrical equipment. In the advent of a major fire, follow the evacuation procedure. Once in a safe location, notify campus security by calling 5000.

-- Utility Failure

In the advent of a power failure, close the mechanical shutter on the laser and close all the optical table enclosure doors. Then follow the evacuation procedure. Once in a safe location, call 5000.

-- Earthquake

Remain inside the 40M Lab and take cover under a desk. After the shaking stops, follow the evacuation procedure.

If it is safe to do so the lasers should be switched off using the standard shutdown procedure. If not, the laser interlock by the exit should be used to shut down the lasers.

Once in a safe location, call 5000.