LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Standard Operating Procedure **LIGO 10-W Laser Operating in the LVEA**		
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1 PURPOSE AND SCOPE

This Document is the Standard Operating Procedure (SOP) for up to two LIGO 10-Watt Lasers operating in the Laser and Vacuum Equipment Area (LVEA). It is designed to ensure the safety of all personnel and equipment in the LVEA. Its role within the overall laser safety plan is described in LIGO-M980042-W, *LIGO Hanford Laser Safety Plan*.

This SOP contains the essential procedures required for the safe operation of one or more LIGO 10-W Lasers in the LVEA and must be approved by both the LIGO Hanford Observatory (LHO) Laser Safety Officer and the LHO Site Safety Officer.

2 LVEA LAYOUT

LIGO plans call for installation of two LIGO 10-W Lasers in the LVEA, one for the two-kilometer-long (2k) interferometer and one for the four-kilometer-long (4k) interferometer. They will be located in the LVEA as shown schematically in Figure 1. They are labeled *2k Laser* and *4k Laser* to signify the interferometer to which each provides laser radiation. The dashed lines denote the locations of the vacuum equipment in the LVEA. The lasers, the ancillary optical components that comprise the Pre-stabilized Laser (PSL) and some of the Input Optics detector subsystem

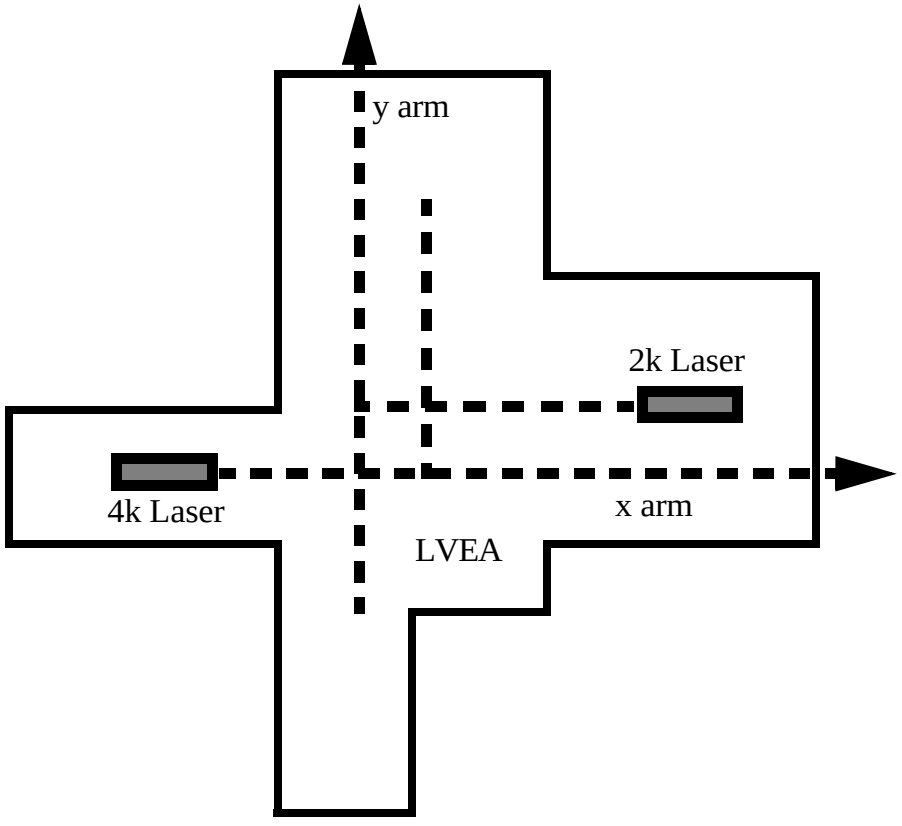

Figure 1: Layout of the laser and vacuum equipment area

(IOO) components are mounted on large (16 ft. x 5 ft. x 2 ft.) optical tables. The optical tables are surrounded by the IOO/PSL Optical Table Enclosures.

3 LASER DESCRIPTION

The LIGO 10-W Lasers are Class IV Nd3+:YAG lasers. They are model 126 MOPA laser systems manufactured by Lightwave Electronics Corp. The output from these lasers are in the near-infrared region of the electromagnetic spectrum and are therefore not visible to the human eye. These lasers emit radiation from two apertures: the main output beam and a sample beam. The relevant operating parameters for the LIGO 10-Watt Lasers are:

MAIN BEAM

- 1064 nm wavelength
- 12 W max. power output
- continuous wave output
- 6.1 kW/cm^2 peak intensity at output aperture

SAMPLE BEAM

- 1064 nm wavelength
- 70 mW max. power output
- continuous wave output
- 36 W/cm^2 peak intensity at output aperture

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 Lasers as described in Section 3, above.

After conditioning by the PSL optics, the beams propagate through the IOO optical components mounted on the IOO/PSL Optical Tables, then exit through apertures in the IOO/PSL Optical Table Enclosures. The beams then propagate through red anodized, aluminum beam tubes, then through windows in the HAM chambers adjacent to the IOO/PSL Optical Tables (HAM 1 for the 4k interferometer or HAM 7 for the 2k interferometer) to the IOO optical components mounted inside the vacuum envelope. After conditioning by the IOO in-vacuum optical components, the laser radiation propagates through the Core Optics (COC) optical components, and therefore throughout the entire vacuum enclosure, including the vacuum equipment located in the Mid- and End-stations. For interferometer sensing and control, laser radiation exits the vacuum envelope through windows in the vacuum chambers and propagate through beam pipes into the ISC table enclosures.

Typically, the LIGO 10-W Lasers will operate unattended, 24 hours per day, seven days per week.

5 CONTROLS

For the purpose of laser safety, two conditions have been defined for the LVEA and VEAs: LASER HAZARD and LASER SAFE.

The LASER HAZARD condition shall exist any time either one or both of the two designated LIGO 10-W Lasers (2-k ifo. and 4-k ifo.) is capable of operating and emitting a beam of laser light in the LVEA.

The LASER SAFE condition shall exist only when the power to all Class IIIb or higher lasers (including the LIGO 10-W Lasers) in the LVEA has been locked out in accordance with *Lockout/ Tagout Procedure* (LIGO-M970144-M). Individual VEAs may be in the LASER SAFE condition when the LVEA is in the LASER HAZARD condition only if a large-diameter gate valve in the beam line between the VEA and the LVEA is in the closed position and locked out.

5.1. Status Controls

The procedure for transitioning to the LASER HAZARD condition is specified in *Procedure for Transition to the LASER HAZARD Condition* (LIGO-M9800047-W). The procedure for transitioning to the LASER SAFE condition is in *Procedure for Transition to the LASER SAFE Condition* (LIGO-M9800048-W).

The switches that control the illumination of the laser warning signs are located on the housings of the warning signs. They are locked out in the LASER HAZARD position when transitioning to the LASER HAZARD condition. The power supplies for the LIGO 10 W Lasers are locked out in the **OFF** position **AND** the shutters in the beam tubes between the IOO/PSL Optical Table Enclosures and the adjacent HAM chambers (Ham 7 for the 2k interferometer and HAM 1 for the 4k interferometer) are locked out in the **CLOSED** position when transitioning to the LASER SAFE condition. This is described in more detail in the transition procedures referenced above.

5.2. Emergency OFF Switches

Emergency OFF switches are located as follows: one in the control room and one on the PSL CDS rack adjacent to the IOO/PSL Laser Table Enclosures (total of three switches).

Activation of any of the Emergency OFF switches shuts down the LIGO 10-W lasers and all other Class IIIb or higher lasers capable of operating in the LVEA. Emergency shutdown from the Mid- or End-stations requires communication with the control room.

5.3. Access Controls

The designated Nominal Hazard Zone (NHZ) includes all of the LVEA and the VEAs at both Mid-stations and both End-stations, the Cleaning Areas in the OSB and the Mid- and End-stations, and the Vacuum Support Equipment areas of the Mid- and End-stations.

Illuminated 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 on the Change Area side of the doors leading from the Change Area to the LVEA, and on the Large Item Access Area side of the door leading from the Large Item Access Area to the LVEA, and near the doors leading into

the Change Areas of the Mid- and End-stations. These signs are illuminated only when the LASER HAZARD condition exists.

All other outside access doors to the LVEA and VEAs are for emergency egress only and are equipped with non-illuminated signs with the message “DANGER VISIBLE AND/OR INVISIBLE LASER RADIATION - AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.”

Additional illuminated signs are mounted near the laser safety warning signs with the message “LASER HAZARD - AUTHORIZED LASER PERSONNEL ONLY EXCEPT WHEN GREEN LIGHT ILLUMINATED.” These signs are illuminated only when the LASER HAZARD condition exists. When the LASER SAFE condition exists, the green LASER SAFE light is illuminated.

Access to the LVEA and VEAs is strictly controlled when the LASER HAZARD condition exists. Only Registered Laser Personnel are authorized to enter the LVEA or VEAs without an escort. The names of all Registered Laser Personnel are posted near the illuminated warning signs in the Change Area of the OSB and in the Large Item Access Area. Names can be added to the list only by the sponsor of this SOP or by the LHO Laser Safety Officer and only after training which satisfies the requirements detailed in LIGO-M980042-W, *LIGO Hanford Laser Safety Plan.*

5.4. Electrical Controls

All control and monitoring functions for the LIGO 10-Watt Lasers are accessed via the laser power supplies (labeled 126 MOPA) located in the PSL CDS racks next to the IOO/PSL optics tables. Most Control and monitoring functions can be remotely activated via the PSL CDS interfaces.

5.5. Beam Controls

A rocker switch 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) equal to or greater than 3.79 for 1064 nm wavelength radiation.

6 OPERATING PROCEDURES

1. The procedure described in *Procedure for Transition to the LASER HAZARD Condition* (LIGO-M980047-W) must have been executed before any Class IIIb or higher (including the LIGO 10-W Lasers) is operated in the LVEA. The LVEA shall transition to the LASER SAFE condition only after execution of the procedure described in *Procedure for Transition to the LASER SAFE Condition* (LIGO-M980048-W).

2. When the LASER HAZARD condition exists, all persons entering the LVEA or VEAs which are in the LASER HAZARD condition are required to wear eye protection, as described in Section 5.6., before entering and at all times while working within the LASER HAZARD areas.
3. Any time one or more persons will be manipulating a LIGO 10-W Laser beam on an IOO/PSL Optical Table OR will be working inside one of the vacuum chambers for one of the interferometers, OR will be manipulating one of the secondary beams from a LIGO 10-W Laser (such as the beams that propagate onto the ISC optical tables), ONE person shall be designated the "Responsible Laser Operator" for that particular interferometer. Anyone requiring access to one of the vacuum chambers or desiring to manipulate the LIGO 10-W Laser beam before it enters the vacuum equipment or one of the secondary beams must coordinate the desired activity with the "Responsible Laser Operator." The name of the "Responsible Laser Operator" for each operating LIGO 10-W Laser shall be posted in the Control Room.
4. **The Responsible Laser Operator is responsible for determining whether or not proposed independent activities can be executed in a safe manner.** He or she must either 1) approve of the proposed activity being carried out simultaneously with his (her) task, 2) determine that it may not occur simultaneously, or, 3) in the event that he (she) does not feel comfortable making the determination, relinquish the role of Responsible Laser Operator.
5. All work requiring access to an IOO/PSL Optical Table Enclosure must be coordinated with either the LHO PSL Liaison, R. Savage, or the LHO IOO Liaison, H. Rong.
6. For any work that requires intrusion into the vacuum envelope, *e.g.* removal of a spool piece or removal of a HAM or BSC door, a work permit that includes a plan for ensuring laser safety during the proposed activities, must be filed and approved.
7. Before and during insertion or removal of any optical component, the power of all affected laser beams shall be reduced to less than 100 mW.
8. 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.
9. Immediately after inserting, removing, or making significant adjustments to any optical component, the immediate vicinity shall be scanned with an infrared viewer or other suitable beam-finding device to ensure that all stray beams are dumped.
10. 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.
11. Any safety-related incident, even a "near miss," must be reported to the LHO Laser Safety Officer and/or the LHO Safety Officer.

It is the responsibility of each person working within the LVEA and VEAs (NHZ) to ensure that LIGO standards for safe laser operation are being followed at all times