



LIGO Laboratory / LIGO Scientific Collaboration

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Enhanced LIGO

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Standard Operating Procedure for the 35-W Nd:YAG
Enhanced LIGO Laser

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This is an internal working note
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1 Purpose and Scope

This document is a draft Standard Operating Procedure (SOP) for the Enhanced LIGO PSL operating within the Laser and Vacuum Equipment Area (LVEA) and the Laser Diode Enclosure (LDE) located within the Short Term Storage Area. The SOP addresses normal day-to-day operation of the laser and does not cover infrequent events such as installation and maintenance, which are addressed in an appendix.

2 The Enhanced LIGO Laser

The main components of the Enhanced LIGO Laser are described in the sections below. The Enhanced LIGO Laser is a master-oscillator power-amplifier similar to the Initial LIGO 10-W Laser. A schematic diagram of the laser is shown in Figure 1. Not shown in the diagram is the shutter located between the acousto-optic modulator and the power amplifier.

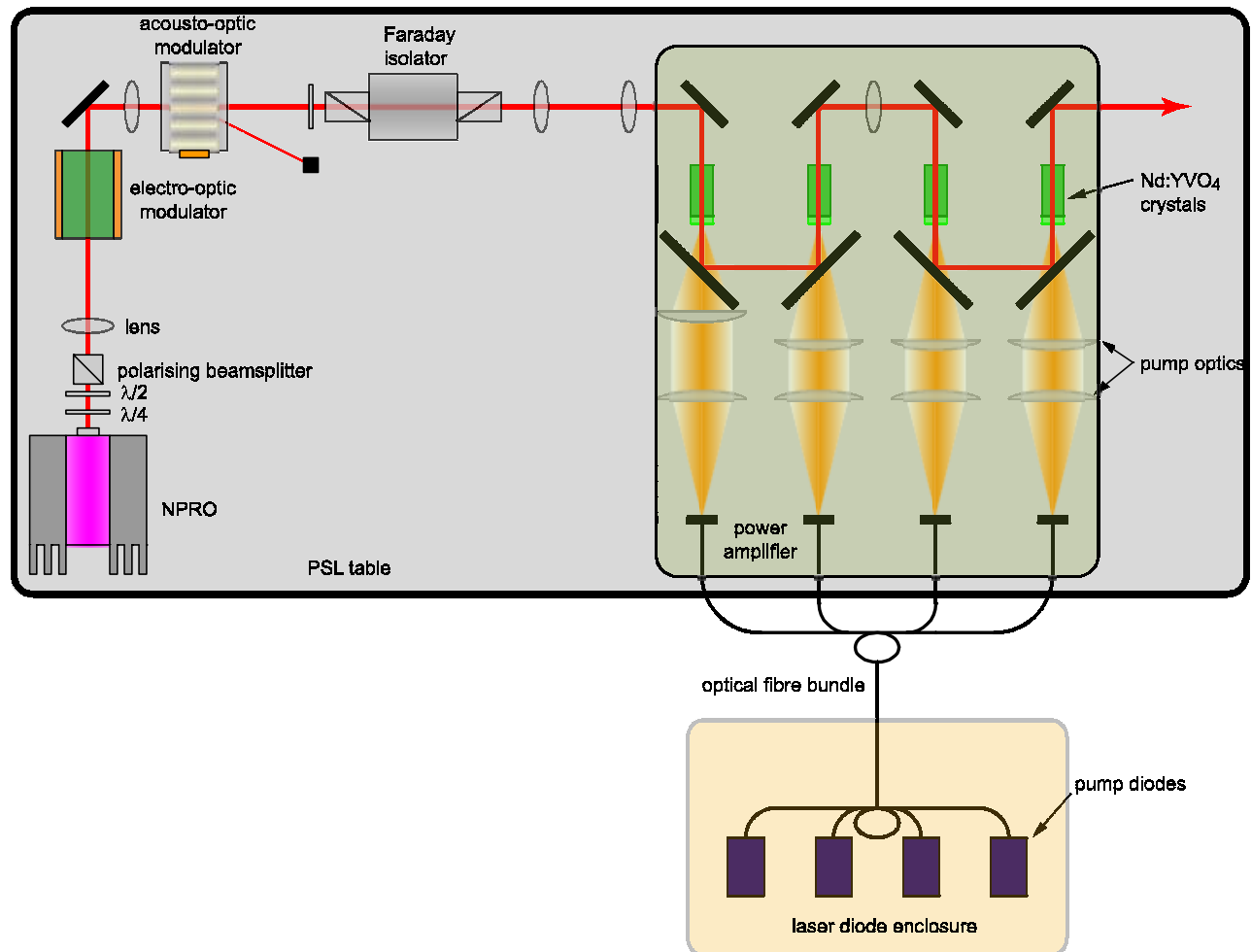


Figure 1. The Enhanced LIGO Laser.

The characteristics of the laser are outlined in Table 1.

Parameter	Value
laser classification	4
output wavelength	1064 nm
maximum output power	50 W
mode of operation	continuous
beam diameter	400 μm
full angle beam divergence	3.4 mrad
output polarisation	vertical to laser base plate

Table 1. The output characteristics of the Enhanced LIGO Laser.

2.1 Control Box

The control box houses the Beckhoff Automation touch panel control computer and is located near the PSL table. All functions necessary to operate the laser are performed via the touch panel computer visual interface. The front and back of the control box are shown in Figure 2.

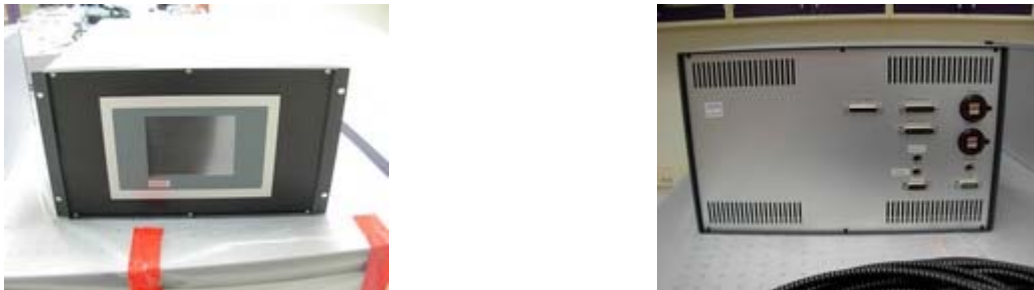


Figure 2. The front and back of the control box.

2.2 Diode Box

The diode box consists of four pump diodes, the necessary cabling to interface to the pump diode power supplies, the plumbing for the water cooling, and a number of Fieldbus modules that allow for monitoring and control of the pump diodes. The pump diodes are mounted to a large water-cooled gold-coated copper plate that acts as a heat sink. The diode box is located in the LDE. The front and back of the diode box is shown in Figure 3.



Figure 3. The front and back of the diode box.

2.2.1 Pump Diodes

The fibre-coupled pump diodes are passively cooled cw diode lasers with a maximum output power of 45 W at a wavelength of (808 ± 3) nm. The emission wavelength of each pump diode is determined by its temperature, which is controlled by a thermo-electric cooler (TEC). The diodes have a typical operating current of 55 A with a maximum operating current of 60 A. The optical fibre core diameter is 400 μm with a numerical aperture of 0.22. The pump diode housing is equipped with an F-SMA 905 connector to mate with the corresponding optical fibre end. The divergence angle of the output beam from the end of the fibre is 222 mrad, which qualifies the pump diode as being an extended source.

2.3 The Laser

The laser consists of a 2-W InnoLight Mephisto non-planar ring oscillator (NPRO) laser followed by a four-stage power amplifier. Each amplifier stage is pumped by a pump diode and has some mode matching optics to couple the pump beam into the Nd:YVO₄ gain medium. The laser is capable of a maximum output power of 50 W. The cover of the laser is interlocked so that removal of the cover will result in a shutdown of the laser.

The laser is equipped with an internal shutter and an external mechanical shutter. The internal shutter is located between the NPRO and the power amplifier. The mechanical shutter is attached to the laser housing next to the output aperture.

The output window of the laser blocks most of the 808 nm pump light. However a small amount (≤ 30 mW) of residual pump light is typically present in the output of the laser. Removal of the output window will result in greater exposure to 808 nm light.

Caution should be exercised when working with the laser, as both 808 nm and 1064 nm radiation are present.

3 Hazards

A Class 4 laser is a hazard to the eye or skin from the direct beam, maybe a hazard from a diffuse reflection, and may also be a fire hazard. From the ANSI Z136.1–2007 standard, a Class 4 laser, in the infrared region, is defined as follows:

Class 4 lasers and laser systems are those that emit radiation that exceed the Class 3B AEL.

The Class 3B AEL, or accessible emission limit, is 0.5 W.

3.1 Identification of Hazards

The most obvious hazard present in the Enhanced LIGO Laser is the emitted laser radiation. Caution should always be exercised in the vicinity of the PSL Table. Other hazards associated with the Enhanced LIGO Laser is the risk of electrical shock when working with the pump diode boxes and their associated power supplies.

3.1.1 Laser Safety Eyewear

Laser safety eyewear with an optical density of at least +4.1 at 1064 nm and +3.2 at 808 nm should be worn at all times when working with the laser and pump diodes.

4 Controls

For the purposes 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 the Enhanced LIGO Laser is capable of emitting a laser beam into the LVEA.

The **LASER SAFE** condition shall exist only when power to all Class 3B and Class 4 lasers in the LVEA has been locked out in accordance with Lockout/Tagout Procedure (LIGO-M970144-A-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 LVEA is in the closed position and is locked out.

4.1 Status Controls

At all times the status of the laser is controlled by the Beckhoff touch panel interface. The status of the laser is indicated in a window located near the bottom of the operator screen.

An illuminated output indicator is located near the output aperture of the laser. Laser radiation is present when the output indicator is lit.

4.2 Access Controls

Both the laser area enclosure and the LDE are restricted access areas. Entry to these areas requires the user to have an access card with the appropriate access clearance. Access clearance is restricted to those who have a need to work on the PSL Table and the laser diode enclosure.

Remote control of the laser is only possible when enabled at the Beckhoff touch panel.

4.3 Electrical Controls

Most of the functions of the laser are accessed through the Beckhoff touch panel. The laser can only be energised once the hardware key interlocks have been enabled. At all times the hardware controls override the software controls.

5 Eye Protection

All personnel working in the laser area enclosure or laser diode enclosure whilst the laser is energised shall wear the appropriate protective laser safety eyewear.

6 Operating Procedures

The components of the Enhanced LIGO Laser are split into two remote areas: the PSL Table and the LDE. This presents some complications to operating the laser, the finer details of which probably need to be worked out and refined as experienced is gained.

When work is being carried out on the PSL which may involve both the PSL Table and the laser diode enclosure, the responsible laser operator has control over access to both areas.

However, it is suggested that when work is being performed on the PSL Table then a sign should be posted near the entrance to the laser diode enclosure stating that work on the PSL Table is underway. Permission to enter the laser diode enclosure must be sought from the responsible laser operator working on the PSL. If the responsible laser operator is not comfortable with this arrangement, locking and tagging out the laser diode power is an available option. Remote control access to the laser controls should also be disabled.

When work is being performed in the laser diode enclosure, a sign should be posted near the PSL Table stating that work is being performed in the laser diode enclosure.

Permission to access the PSL Table must be sought from the responsible laser operator working on the PSL. The option to lock and tag out the PSL Table is available to the responsible laser operator. The use of which is at their discretion. Remote access to the laser controls should be disabled.

6.1 Powering Up

Prior to powering up the laser, the operator shall visually confirm either personally or via the surveillance camera, that no one is physically in the direct path of the beam. In addition the operator shall check that the laser safety warning signs are in place and are operational. The interlock key can then be engaged and the laser turned on. The appropriate remote control access status should then be updated on the Beckhoff touch panel.

6.2 Powering Down

Powering down, in this context, means the complete shutdown of the laser, as opposed to placing the laser on standby. In powering down the operator shall update the status of the laser on the Beckhoff touch panel. Afterwards the system off button is enabled and the interlock key removed from the key switch.

6.3 Manipulation of Optical Components

Prior to adjusting any optic or optical mount that will affect the main beam path, a visual check shall be performed to confirm that no personnel are in the beam path. If more than one person is present in the vicinity, an announcement stating that the operator intends to adjust the main beam and in what manner is recommended. The operator should

exercise caution if wearing jewellery, preferably making the adjustments using the other hand if removal of the jewellery is not desired. After completion of the adjustment to the main beam path has been performed, a scan around the PSL Table shall be performed with an infrared viewer to check for any inadvertent stray beams. Any stray beams found should be dumped in the appropriate manner.

Manipulation of objects in the secondary beam paths such as those to the diagnostic breadboard and reference cavity shall follow the steps outlined in the preceding paragraph.

Activities that affect the beam going into the LVEA shall be cleared with the control room.

7 Training

Each user of the PSL shall undergo basic laser safety training as required by the LIGO Laser Safety Program. In addition, each user shall receive a walk around of the PSL area and LDE from the cogniscent PSL liason. The walk around shall give an up-to-date description of the PSL area and LDE and any particular hazards known to be present at that time. Access to the PSL and Enhanced LIGO Laser will be on an “as needed” basis only. It is envisaged that access will be stricter than that implemented for Initial LIGO.

Upon completion of these requirements, the user’s name will be added to the list of personnel authorised to operate the Enhanced LIGO Laser.

8 Responsibilities

It is the responsibility of each person working with the Enhanced LIGO Laser to ensure that safe laser practices are being followed at all times.

Should any practice seem flawed and can be improved upon, it is encouraged that any suggested improvements be brought forth to the appropriate laser safety officer.

9 Appendix

9.1 Installation

Particular care should be paid during installation because of the work required to connect the optical fibres. When making a physical connection involving the optical fibres, the pump diodes shall be powered off. All work involving the optical fibres should be performed in a Class 1000 environment with the mobile HEPA unit blowing over the work area.

Connections to the pump diodes shall be made prior to connecting the other end of the fibre to the power amplifier. The integrity of the optical fibres should be checked with a power meter before connecting to the power amplifier.

9.2 Maintenance

The same precautions taken during installation should be followed during maintenance.

10 References

- American National Standard for Safe Use of Lasers, ANSI Z136.1-2007
Laser Institute of America, ISBN 0-912035-65-X