

# Glowforge Pro LSO Training

Version 1.0.1

## Introduction

Safe operation of your Glowforge Pro requires a trained Laser Safety Officer (LSO). Glowforge has consulted with laser experts to design these Glowforge Pro LSO Training Materials to help you in complying with your LSO responsibilities and ensure that you operate your Glowforge Pro safely.

The first document, the Glowforge Pro LSO training, has three parts:

- The first section, “Glowforge Pro Safe Operation”, describes the procedures to ensure safe operation.
- The second section, “Laser Safety Officer Responsibilities”, describes your role as the Laser Safety Officer for your Glowforge Pro.
- The third section, “About Lasers and Laser Safety”, describe general information about lasers and laser safety as well as regulations pertaining to lasers.

The second document, “Glowforge Pro Laser Safety Program”, is a laser safety program document that you, as the LSO for your Glowforge Pro, may adopt.

The third document, “Glowforge Pro Laser Standard Operating Procedure”, is an SOP document that you may adopt that is a part of the Glowforge Pro Laser Safety Program.

The fourth document, “Warning Sign”, is a sign you may choose to use as a compliance measure described in the SOP, if you decide not to operate your Glowforge Pro in Class 1 conditions.

## Glowforge Pro Safe Operation

### Class 1 Conditions

Your Glowforge Pro is a Class 4 laser. However, certain safety precautions may create “Class 1 conditions” around the laser. Class 1 conditions mean that the conditions are incapable of producing damaging radiation levels during normal operation.

That means that if you choose to use the Pro Shields or Proofgrade materials as described below, additional protections such as safety glasses, signs, and warning lights are not necessary.

However, even with Class 1 conditions, every person who uses the Glowforge Pro must read and abide by the user manual and all instructions in the Glowforge App.

## *Pro Shields*

Pro Shields may be available for your Glowforge Pro. These serve as a beam block for the passthrough slot. When the passthrough slot of the Glowforge Pro is not in use, these may be screwed in tightly to close the front and rear openings. When the Pro Shields are installed and all instructions in the manual and the Glowforge App are followed, Class 1 conditions exist, and no further laser safety precautions are required beyond compliance with the manual and Glowforge App.

## *Proofgrade™ Materials*

When the Pro Shields are removed, the crumb tray is properly installed, all instructions in the manual and the Glowforge App are followed, and Proofgrade materials are in use, Class 1 conditions exist. The laser operator must prevent children and untrained users from accessing the Glowforge Pro.

## Operation Outside of Class 1 Conditions

If your Glowforge Pro is not being operated under Class 1 conditions, you are responsible for ensuring safe operation. The provided SOP does not permit safe operation in Class 4 conditions, so the LSO must create an SOP that does. Ultimately, the LSO is responsible for defining what that entails and describing and enforcing it with that SOP, and the laser operator is responsible for ensuring compliance and safe operation. Some key elements of a Class 4 SOP may include:

### *Appropriate safety glasses*

Glowforge provides a pair of safety glasses appropriate for use with your Glowforge Pro under Class 4 Conditions. Glowforge also sells additional pairs; contact [support@glowforge.com](mailto:support@glowforge.com) for more information. This hazard analysis (below) shows that the Glowforge provided glasses are appropriate for use.

### *Sign*

An appropriate laser safety sign placed at the entryway to alert people to the hazards inside. Glowforge has provided a sample sign (below).

### *Light*

A light outside the door that the user switches on before beginning to use the laser to indicate that the laser is in use. A battery-powered LED light may be used.

### *Entry controls*

Procedural controls are sufficient to limit entry, whereby a sign and light indicate the presence of an operating Class 4 laser, and there is no direct line of sight from the laser output to the door.

## *Door Interlock*

While not required, an interlock switch on the door may be connected to the rear interlock port of the Glowforge Pro to allow for a defeatable or non-defeatable door interlock. The rear interlock connector on the Glowforge Pro comes installed with a bypass which allows operation. If the bypass is removed and the interlock is connected to a door switch, then the laser will only operate when the door switch is closed.

# Laser Safety Officer Responsibilities

## The LSO and Your Laser Safety Program

ANSI Z136.1 describes guidelines for a safety program that will minimize the hazards of a Class 4 laser like the Glowforge Pro. Primary safety responsibility rests with someone designated as the Laser Safety officer, or LSO. This document is designed to assist you in acting as the LSO for one or more Glowforge Pro units. It does not provide sufficient information to advise you in acting as the LSO for any other laser.

The LSO verifies the classification of the laser. The LSO determines the level of hazard by considering the details of the laser, and creates a standard operating procedure (SOP) that determines what control measures (like additional interlocks, training, and safety glasses) should be used.

The LSO is then responsible for helping and training other laser users, ensuring safe compliance, analyzing any possible hazards, providing safety equipment, ensuring all regulations are complied with including (in the US) CDRH, OSHA, and state regulations, and auditing the use of the laser to make sure it's used safely.

Beyond these responsibilities, the LSO must also recommend and approve signs, labels, protective equipment, facilities, equipment, any modifications, maintain records, approve laser system operation, and investigate accidents should one occur. The LSO is ultimately the one responsible for determining if and how a laser may be safely operated.

## Hazard Analysis

The LSO must analyze the hazards present in the lasers for which they are responsible. The LSO may rely on an expert for execution of the hazard analysis. Pat Harris, a recognized expert on laser safety, has created a hazard analysis (provided below) of the Glowforge Pro that you may choose to use in your laser safety program.

## Standard Operating Procedure

Based on the Hazard Analysis, the LSO must create a Standard Operating Procedure (SOP) that describes the control measures required to minimize hazards. Laser safety expert Pat Harris has also created a sample SOP (provided below) that you may use or adapt to your Glowforge Pro laser safety program.

## About Lasers and Laser Safety

### How Lasers are Different

Lasers are a special kind of light source. Most light is made of many different colors, all shining out in lots of directions at once. Laser light is different in three ways.

First, laser light is monochromatic - just one color. Sometimes that color is visible, like the low-power red laser that you can see your Glowforge use to measure material when it's focusing. Sometimes it's invisible, like the high power infrared laser beam your Glowforge uses to cut and engrave material.

In technical discussions, people describe lasers as producing "nonionizing electromagnetic radiation". That describes a broad category that includes everything from sunshine to radio waves. Instead of talking about color, they use the term "wavelength". The wavelength of the low power measuring laser on your Glowforge is 650 nanometers, which is red. The wavelength of the powerful printing laser is 10,600 nanometers, which is invisible infrared.

The second difference between laser light and regular light is that laser light is directional. That means that it can be made to travel in a straight line, in a beam, without spreading out much.

The third difference is that laser light is coherent. That means that each lightwave is synchronized with the others.

It's very hard to get light to move in a straight line, without spreading out. If the waves aren't lined up, or if there's a mix of colors and directions, the beam will spread out. Lasers, however, can stay lined up for a long distance - and, importantly, can be focused down to a point.

Lasers greatest effectiveness - and danger - as compared to ordinary light comes from lasers' ability to be focused.

### Laser Background

The very first laser used a strobe light and a ruby crystal. The light from the strobe was amplified in the ruby crystal, stimulating it to emit nonionizing electromagnetic radiation at

694 nanometers. The acronym "LASER" comes from this experiment - light amplification through stimulated emission of radiation.

These first lasers were called "solid state" lasers because the action parts were solid crystals. Shortly after the development of solid state lasers came gas lasers, which can resemble neon signs. Electricity causes gas in a tube to glow. Specially tuned mirrors amplify the light, and the laser beam emerges. The infrared printing laser in your Glowforge is a gas laser. It uses a mixture of gasses, but the gas that actually creates the beam is Carbon Dioxide, also known as CO<sub>2</sub>.

One of the most recent lasers to be invented is the diode laser. Diode lasers are small electrical devices that are made like microchips and LEDs. They turn power directly into laser light. You may have seen one before in a laser pointer. The low power red measuring laser in your Glowforge is a diode laser.

## Measurements

There are four measurements used to describe the effect of a laser.

Joules measure energy. If you shine light at a gram of water until it absorbs 1 joule of energy, the water will heat by about a quarter of a degree celsius.

Watts measure power. If you turn on a one-watt light for a second, it will put out 1 joule during that time.

Joules per square centimeter measures radiant exposure. If you focus down that one-watt light to a square centimeter of paper and shine it for a second, that one joule will spread over the paper, and it will heat up slightly, just like the water. However, if you focus it down to 1/100th the size, the paper may singe and turn brown.

Finally, watts per square centimeter measures irradiance. If you keep shining that one watt light on the paper, it will keep adding joules of energy. If it's focused to one square centimeter, it will slowly warm. If it's focused to 1/100th the size, the paper may catch fire.

## Laser Beam Hazards

Laser beams can be hazardous because the energy of the laser can damage eyes and skin. If the main infrared laser in your Glowforge Pro strikes tissue, it will heat the tissue. This can cause damage to both eyes and skin. The risk is higher if the laser is more powerful, if it is more focused, and if it stays in one place for a longer time, so all of these factors are considered when assessing safety.

The laser beam can strike a person in one of three ways. First, the laser can be pointed at the person directly. Second, in 'specular reflection', the laser can be reflected towards a person. Third, in 'diffuse reflection', the laser strikes a surface that is not a mirror, and scatters the light in all directions. Because the light from a diffuse reflection is scattered, it is not as hazardous as the direct or reflected light - but there may still be enough intensity to cause damage.

While any part of the body may be damaged by a laser beam, the eye is particularly sensitive and vulnerable. The far-infrared like the beam from CO2 lasers is absorbed by the cornea in front of the eye; therefore, unlike many other lasers, it is not a retinal hazard.

## Laser Hazard Classes

Lasers are classified by the level of radiation that may be encountered during normal operation.

Class 1 lasers are incapable of causing injury during normal operation. Class 1M lasers are the same, except unless magnifying optics are used. The red measuring laser in the Glowforge Pro is a Class 1 laser.

Class 2 lasers are incapable of causing injury in less than 0.25 seconds. Class 2M lasers are the same, except unless magnifying optics are used.

Class 3R lasers are marginally unsafe if the beam is directed at the eye. Class 3B lasers are hazardous if the beam is directed at the eye, but are usually not an eye hazard if the beam is scattered.

Class 4 lasers are eye and skin hazards for both direct and scattered exposure. The infrared printing laser in the Glowforge Pro is a Class 4 laser.

## Laser Regulations

In the US, laser manufacturers like Glowforge are regulated by the Center for Devices and Radiological Health (CDRH), and required to follow 21 CFR 1040.10 and 1040.11, which are federal law. In many other countries (but not the US), both laser manufacturers and laser users are required to follow IEC60825.

ANSI Z136.1 is a voluntary standard that describes how to use lasers safely. OSHA (a US federal law that applies to workplaces but not to private homes) requires a safety program like that described in the ANSI standard.

The CDRH requires that Class 4 laser devices have a defined set of safety features. The case of the Glowforge Pro prevents access to excess laser radiation and serves as the protective housing. Safety interlocks disable the laser if the lid is opened. A remote interlock connector on the back of the Glowforge Pro allows you to connect a separate interlock, such as a switch on the door to the room, that disables the laser and requires the laser to be restarted before it can be used again. The password to your account serves as the master key control for your Glowforge Pro that prevents unauthorized laser operation. The button of the Glowforge Pro serves as the emission indicator; if it is illuminated, laser light may be present. The controls are located so that laser exposure is not required to operate them, and all viewing optics limit exposure to Class 1 levels. There are also certain labels present required by US and some international laws.

There may be other laser regulations depending on your country, state, and even city, and regulations may change. This information is provided to assist you in creating a safety program as described by ANSI Z126.1, but cannot advise you on legal compliance.

## Non-Beam Hazards

There are additional hazards to your Glowforge Pro. Always operate your Glowforge Pro in accordance with the manual and follow all instructions in the Glowforge App to minimize hazards.

### *Electrical*

Your Glowforge Pro uses a high-voltage power supply. Overriding the safety interlocks, operating a laser where the case is damaged, unauthorized service, or any other use in violation of the manual may expose you to hazardous and even lethal voltages.

### *Laser Generated Air Contaminants*

When using a laser to process materials, a variety of air contaminants may be produced that can be hazardous. The air must be filtered to remove those contaminants. Follow the user manual in your Glowforge Pro to ensure that all exhaust is either properly treated or discharged outdoors where it can safely dissipate.

### *Process Nonionizing Radiation*

Processing metals with a laser may result in the release of ultraviolet light. If your Glowforge Pro produces a bright light that cannot be viewed comfortably, look away.

### *Collateral Nonionizing Radiation*

The material that produces the laser beam may emit harmful levels of UV and/or IR light. The Glowforge Pro has been tested to ensure that harmful levels are not present outside the case or when viewed through the glass lid.

# Glowforge Pro Laser Safety Program

## SCOPE

This program applies to **Glowforge Pro Laser** operated by **Glowforge Pro Owner**. This program is based on guidance of ANSI Z136.1-2014, *American National Standard for Safe Use of Lasers*. The proper implementation of this program will assure that laser exposures are always below the maximum permissible exposure (MPE) limits.

## LASER SAFETY OFFICER

An individual designated as the Laser Safety Officer (LSO) shall have the responsibility and authority to assure compliance with this program. The LSO shall:

- Provide hazard evaluations for Glowforge Pro laser
- Specify control measures for the Glowforge Pro laser and assure implementation
- Approve procedures, SOPs, protective equipment, signs and labels
- Assure that all laser personnel receive appropriate safety training
- Monitor the program and assure compliance
- Maintain program records

The LSO shall have final authority in determining Glowforge Pro laser control measures and may approve alternate controls when these are appropriate based on the judgment of the LSO. Glowforge Pro laser shall be operated only with approval of the LSO. The LSO shall have the authority to terminate laser operations at any time.

## LASER CLASSES

Class 1 laser systems are incapable of producing damaging radiation levels during normal operation and are exempt from any control measures. Class 1 laser systems may contain higher class lasers and may produce laser hazards if operated with interlocks defeated. Only authorized personnel may operate class 1 laser systems with interlocks defeated. Operators of class 1 laser systems with embedded class 3B or class 4 lasers shall receive a laser safety briefing.

Class 1M laser systems are incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with optical instruments. Operators of class 1M laser systems shall receive a laser safety briefing.

Class 2 laser systems emit visible light only at a power level of 1 milliwatt or less. The normal aversion response to bright light is adequate protection. Staring into the beam of a class 2 laser is hazardous. Operators of class 2 laser systems shall receive a laser safety briefing.

Class 2M laser systems emit visible light only. The normal aversion response to bright light is adequate protection for unaided viewing. However, viewing the beam with optical aids is potentially hazardous. Operators of class 2M laser systems shall receive a laser safety briefing.

Class 3R laser systems are potentially hazardous under some viewing conditions, but the probability of an actual injury is small, and the control measures for safe use are straightforward. Most laser pointers fall in this class. Operators of class 3R laser systems shall receive a laser safety briefing. (Most lasers previously classified as class 3a fall in this category.)

Class 3B laser systems are eye hazards for intrabeam viewing and specular reflections, even for momentary exposures, but diffuse reflections are not usually hazardous. Class 3B laser systems shall be operated only in laser controlled areas by authorized operators. Operators of class 3B laser systems shall receive approved laser safety training.

Class 4 laser systems are eye hazards and skin hazards for intrabeam exposures, specular reflections, and diffuse reflections. They are also fire hazards and may produce laser generated air contaminants. Class 4 laser systems shall be operated only in laser controlled areas by authorized operators. Operators of class 4 laser systems shall receive approved laser safety training. A written Standard Operating Procedures (SOP) is required for class 4 laser operation. The **Glowforge Pro Laser** is certified with the FDA under the Code of Federal Regulations Title 21 as a class 4 laser system.

## TRAINING REQUIREMENTS

When operating in Class 1 conditions, all users will read and obey the safety manual and Glowforge App software. When operating in Class 4 conditions, additional laser safety training is required and must be prepared and administered by the LSO.

If there are bystanders, children, or if the Glowforge Pro Laser is used in a public setting where untrained individuals may be present, feed-through beam blocks must be securely installed.

## CONTROL MEASURES

The requirements for the **Glowforge Pro Laser** controlled area shall be determined by the LSO. The minimum requirements considered by the LSO for the **Glowforge Pro Laser** controlled area are:

- If needed entryway controls to allow only authorized personnel or approved spectators to enter the **Glowforge Pro Laser** control area. (Administrative controls are acceptable.)
- Laser safety eyewear available and used in accordance with the SOP for the **Glowforge Pro Laser**.
- Beam control (barriers and beam blocks) to limit laser hazards within the controlled area.
- Written SOP for the **Glowforge Pro Laser**.
- Training of the **Glowforge Pro Laser** operators.

## EYEWEAR POLICY

Laser safety eyewear is not normally required for the operation of the **Glowforge Pro Laser** when operating in Class 1 conditions as described in the SOP. The LSO will require eyewear or approve laser operation without eyewear based on a hazard evaluation performed by the LSO or the LSO may choose to delegate this responsibility.

## RESPONSIBILITIES OF EMPLOYEES WORKING WITH LASERS

Employees who work with the **Glowforge Pro Laser** with the beam exposed shall:

- Energize or work with lasers only when authorized to do so.
- Comply with laser safety rules and work procedures.

- Notify their supervisor or the LSO in case of potential accident or injury or suspected unsafe condition.

## LASER SAFETY AUDIT

At an interval determined by the Laser Safety Officer, the **Glowforge Pro Laser** will be audited for safety:

- 1) It will be visually inspected for damage.
- 2) The most recent user version of the manual will be re-read.
- 3) The laser will be energized and the lid opened to confirm that the interlocks correctly interrupt operation.
- 4) The Laser Safety Program will be reviewed to ensure that the program is current and compliant.

A record of this audit will be completed, printed, signed, dated, and retained.

## RECORDS

The LSO shall maintain records which document the Laser Safety Program. These records shall include:

- Laser hazard analysis reports for the **Glowforge Pro Laser**
- A list of operators who have been trained and permitted to use the **Glowforge Pro Laser**
- Standard Operating Procedures for the **Glowforge Pro Laser**
- Approvals of alternate laser control measures, if implemented
- Laser Safety Audit checklist

# Glowforge Pro Laser Standard Operating Procedure (SOP)

**Scope:** This SOP applies to the normal operation of the **Glowforge Pro Laser** as specified by the manufacturer.

1. **System Description:** Two axis carbon dioxide laser material processing system. This is a class 4 laser system that is normally operated under class 1 conditions (ANSI Z136.1, 4.4.2.7.2.1).

Wavelength: 10.6  $\mu\text{m}$

Maximum Power: 45 W

Operating Mode: Continuous Wave

Beam Diameter: 5 mm

Beam Divergence: 2.7 mrad ( $M2 = 1$ )

2. **Potential Hazards**

- A. Eye hazard from direct, reflected or scattered beam.
- B. Skin hazard and fire hazard.
- C. Electrical hazard inside power supply.
- D. Laser Generated Air Contaminants.

3. **Control Measures**

- A. The LSO will only allow physical access to the laser to users who have been enrolled in the Glowforge App software and thereby received safe operating instructions.
- B. All users of the Glowforge Pro Laser will comply with the user manual and all instructions in the Glowforge App software at all times.
- C. The **Glowforge Pro Laser** shall be operated in class 1 conditions per ANSI Z136.1, 4.4.2.7.2.1 (reference Hazard Analysis Report). Class 1 conditions shall be considered fulfilled when operating under the following guidelines.
  - a. The laser system shall be operated with all manufacturer safety features fully functional.
  - b. When the material feed-through is not in use the feed-through beam blocks ("Pro Shields") shall be securely in place.

- c. When utilizing the material feed-through, only Proofgrade™ materials are used.
  - D. Do not place an unprotected eye at the feed-through opening.
  - E. Do not operate the Glowforge Pro with bystanders, children, or in a public setting without the feed-through beam blocks securely installed.
  - F. Keep all combustibles, tool, and reflective surfaces away from the beam path. Make sure you know where the beam is and stay clear.
  - G. Work involving access to the power supply shall be done by the manufacturer with no exceptions.
  - H. Maintenance shall be done with the laser system turned off.
  - I. When functioning normally, the exhaust system will remove LGACs to maintain levels that are not hazardous or irritating.
4. **Required Training:** When operating in Class 1 conditions, all users will read and obey the safety manual and Glowforge App software. When operating in Class 4 conditions, additional laser safety training is required and must be prepared and administered by the LSO.

5. **For emergency medical response call \_\_\_\_.**

Report all incidents to the LSO.

6. **Authorized Personnel**

The following personnel are authorized to operate this system:

---

---

---

---

---

---

---

# Glowforge Pro Laser Hazard Analysis Report

## Laser Description:

Glowforge Pro 45 watt CO2 laser

Manufacturer:	Glowforge, Inc.
Model Number:	na
Serial Number:	na
System Classification:	4
Operating State:	Continuous Wave (CW)
Report ID:	170731103846
Date of Analysis:	07/31/2017
Laser Owner:	na
Laser Safety Officer:	na
Laser Location:	na na na

## LASER INPUT DATA

Wavelength:	10.6 um
Mode of Operation:	Continuous Wave
Average Power	4.5E+01 W
Pulse Duration:	na s
Pulse Repetition Rate:	na Hz
Group Duration:	na s

Group Repetition Rate:	na Hz
Exposure Duration:	1E+01 s
Successive Day Exposure:	No
Optically Aided Viewing:	No
Atmospheric Attenuation:	0 cm <sup>-1</sup>
Beam Measurement Criteria:	(1/e <sup>2</sup> )
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	5E+00 mm
Major Axis Divergence:	2.7E+00 mrad
Major Axis M-Squared:	1
Minor Axis Diameter:	5E+00 mm
Minor Axis Divergence:	2.7E+00 mrad
Minor Axis M-Squared:	1
Intrabeam Observer Range:	5E-01 m
Focal Length of Lens:	5E+01 mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	5E+00 mm
Minor Diameter on Lens:	5E+00 mm
Lens Observer Range:	0 m
Fiber Optic Type:	none
MFD / NA:	na
Fiber Optic Observer Range:	na m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	8E+01 deg
Beam Diameter on Target:	1E-03 mm
Diffuse Observer Range:	2.5E-01 m

Diffuse Exposure Duration: 6E+02 s

### **LASER SAFETY RESULTS**

#### **Intrabeam/Lens-on-Laser(LoL)/Fiber Exposure**

Point Source Ocular MPE: 1E-01 W/cm<sup>2</sup>

**Worst Case Optical Density: 3.67 OD**

OD at Intrabeam Obsr. Range: 3.45 OD

OD at Lens Obsr. Range: 3.67 OD

OD at Fiber Optic Obsr. Range: 0 OD

Skin MPE: 1E-01 W/cm<sup>2</sup>

Times Skin MPE: 4.7E+03

#### **NOHD/NHZ Values**

**Intrabeam Eye NOHD: 1.25E+02 m**

**Point Source Eye Dif Ref NHZ: 5E-02 m**

Skin Dif Ref NHZ: 5E-02 m

**Lens-On-Laser Eye NOHD: 3.4E+00 m**

Fiber Optic Eye NOHD: 0 m

### Diffuse Reflection Exposure

Source Type:	Point
Ocular MPE:	1E-01 W/cm <sup>2</sup>
Point Source Eye NHZ	5E-02 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0 OD
Fraction of Ocular MPE:	1E+00
Skin MPE:	1E-01 W/cm <sup>2</sup>
Times Skin MPE:	4E-02

### OTHER CALCULATED VALUES

Average Power:	4.5E+01 W
Peak Pulse Power:	na W
Energy per Pulse:	4.5E+02 J
Duty Cycle:	1E+02 %
Average Power of Group:	na W
Pulses per Group:	na

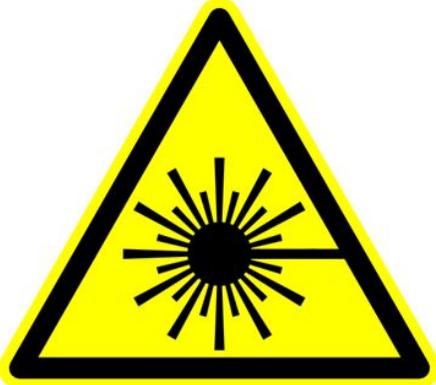
Groups per Exposure:	na
Pulses per Exposure:	na
Major Diameter at Range:	5.2E+00 mm
Minor Diameter at Range:	5.2E+00 mm
Peak Irradiance in Eye LA:	na W/cm <sup>2</sup>
Avg Irradiance in Eye LA:	2.8E+02 W/cm <sup>2</sup>
C <sub>A</sub> :	na
C <sub>B</sub> :	na
C <sub>C</sub> :	na
C <sub>E</sub> :	na
C <sub>p</sub> (Point Source RP only):	na

**Notes:**

The worst case Optical Density (OD) requirement for laser protective eyewear is 3.67. The eyewear provided by the laser manufacturer is rated at a minimum of OD 4. The exposure duration used to determine the OD is the ANSI default duration for an accidental exposure of 10 seconds.

With all the manufacturer safety features fully function and the laser operating per the SOP the only source for a possible exposure above the Maximum Permissible Exposure (MPE) is a diffuse reflection that could scatter the laser output through the feed-through opening. Very conservative assumptions are made in this analysis. Exposure duration used is 600 seconds which assumes intentional viewing. The scattered power is assumed to be 45 watts which is an absolute worst case. The viewing angle is assumed to be 80 degrees. Greater viewing angles create a smaller hazard distance. The viewing angle in this case is closer to 85 degrees or more so a conservative assumption is 80 degrees. Given the assumptions the diffuse nominal hazard zone (NHZ) is about 5 centimeters or just under 2 inches. This NHZ is insignificant. Operating per the SOP the laser system fulfills the ANSI 4.4.2.7.2.1 requirement for operation under class 1 conditions.

# Warning Sign

 <b>WARNING</b>	
	<p><b>Class 4 Laser Controlled Area</b></p> <p>Laser Radiation Avoid Direct Eye Exposure to Direct and Scattered Radiation Do Not Enter When Light is Illuminated</p> <p>Laser Eye Protection Required</p> <p>OD 4 @ 10,600 nm</p> <p>Laser Type: Carbon Dioxide Max Power: Less than 100 watts</p> <p>Laser Safety Officer: _____ Ext. _____</p>