Operational Safety Procedures (OSP)

For The

Target Bay

At The

Texas Petawatt Laser

Document Number
TPW-D-0013-C

Center for High Energy Density Science
The University of Texas at Austin
Austin, TX 78712

Table of Contents

1 Introduction 2
2 Target Bay Overview 2
2.1 Entry Region 4
2.2 Laser Diagnostics Area 5
2.3 Compressor Cleanroom 5
2.4 High F-number beamline clean area (TC2) 5
2.5 High intensity target area (TC1) 5
2.6 Radiation shield walls 5
2.7 Passages 6
2.8 Engineered Optical Hazard Mitigation 6
2.9 Regions outside the Target Bay 6
2.9.1 Pulsed power room (“cave”) and Catwalk 6
2.9.2 Laser Bay 6
2.9.3 Control room 7
3 Operators, Authorized Personnel, and Visitors 7
3.1 Operators 7
3.1.1 Laser Operators 7
3.1.2 Shot Director 7
3.1.3 Pulse Power Operators 7
3.1.4 Vacuum Operators 8
3.1.5 Crane Operators 8
3.2 Target Bay Authorized Personnel (AP) 8
3.3 Short Term Visitors 9
4 Hazard modes and communication 9
4.1 Optical hazard 10
4.1.1 Class IV lasers 11
4.1.2 Class IIIb / IIIR lasers 11
4.1.3 Class IIIa and below 12
4.1.4 Protective eyewear 12
4.2 Hazard Level Communication 12
4.2.1 Laser Warning Lights 12

4.2.2 Interlock Status Panels 14
4.2.3 Public Announcement (PA) System 17
4.3 Target area laser hazard modes 17
4.3.1 ALL CLEAR 17
4.3.2 LASER ON 19
4.3.3 WARM UP 21
4.3.4 ROD SHOT 23
4.3.5 NO ENTRY 26
4.3.6 Summary of announcements for changing laser safety state 27
4.3.7 ISP maintenance 28
4.4 Radiological hazards 28
4.4.1 On-shot radiation 28
4.4.2 Nuclear activation 29
5 Cleanliness protocol 31
6 Facility contacts 31
6.1 Pulsed Power Room Operators 31
6.2 Laser Operators 31
6.3 Vacuum Operators 32
6.4 Crane Operators 32
6.5 Emergency Contacts 32
6.6 Miscellaneous 32
7 SOP Revision History 35

1 Introduction

The purpose of this document is to describe approved safe operating procedures for the Target Bay of the Texas Petawatt Laser Facility. These are in addition to the lab safety procedures and laser safety procedures provided by the University of Texas Environmental Health & Safety (UT EH&S) office, which can be found on their website (http://www.utexas.edu/safety/ehs/index.php). This document is not intended as a comprehensive safety manual, and does not replace institutional laser safety training. Proper performance of these procedures is mandatory to be a qualified user of the Texas Petawatt Target Bay in good standing. While it is our goal to provide engineered controls to physically limit the possibility of accident, these cannot ensure by themselves a completely safe environment. Personnel and visitors must therefore adhere to safe standard operational procedures.

> **It is expected that everybody in the Target Bay is concerned for each other's safety, BUT each person is ultimately responsible for their own safety. If any worker in the Target Bay has a concern regarding safety, that worker is qualified to safely halt work until such time that there is no cause for concern.**

The Target Area RI, Gilliss Dyer has a master copy of this document. At the end of the document is a signature sheet signed by every visitor, user, or operator authorized to enter the target area without supervision. This is the complete list of Authorized Personnel (AP) for the target bay. AP can perform work in the Target Bay in approved areas described below. *For scientists and students from institutions other than UT, active Visiting Researcher status with UT is required for AP status.*

It is important to note that authorization to work in the Target Bay does not imply authorization to enter or work in the Laser Bay, Compressor Cleanroom, or Laser Diagnostic Area, or to perform work on the Catwalk. These regions are defined in Section 2. The OSP for access to the Laser Bay is document TPW-D-0011. The OSP for access to the Catwalk is document TPW-D-0012.

A list of Responsible Individuals (RIs), important phone numbers and revision management can be found on the last pages of this document.

2 Target Bay Overview

The Texas Petawatt (TPW) Laser produces pulses containing up to 200 J of energy at 150 fs pulse duration, with a central wavelength of 1057 nm. Any of the Laser Operators can provide detailed technical documentation of the laser design upon request. The

amplification stages of the Texas Petawatt are contained in the Laser Bay (see document TPW-D-0011). Vacuum chambers for pulse compression, beam transport, and laser-target interaction are located in the Target Bay, along with laser diagnostics and the ground terminal for the High Voltage Pulsed Power System (OSP document TPW-D-0012).

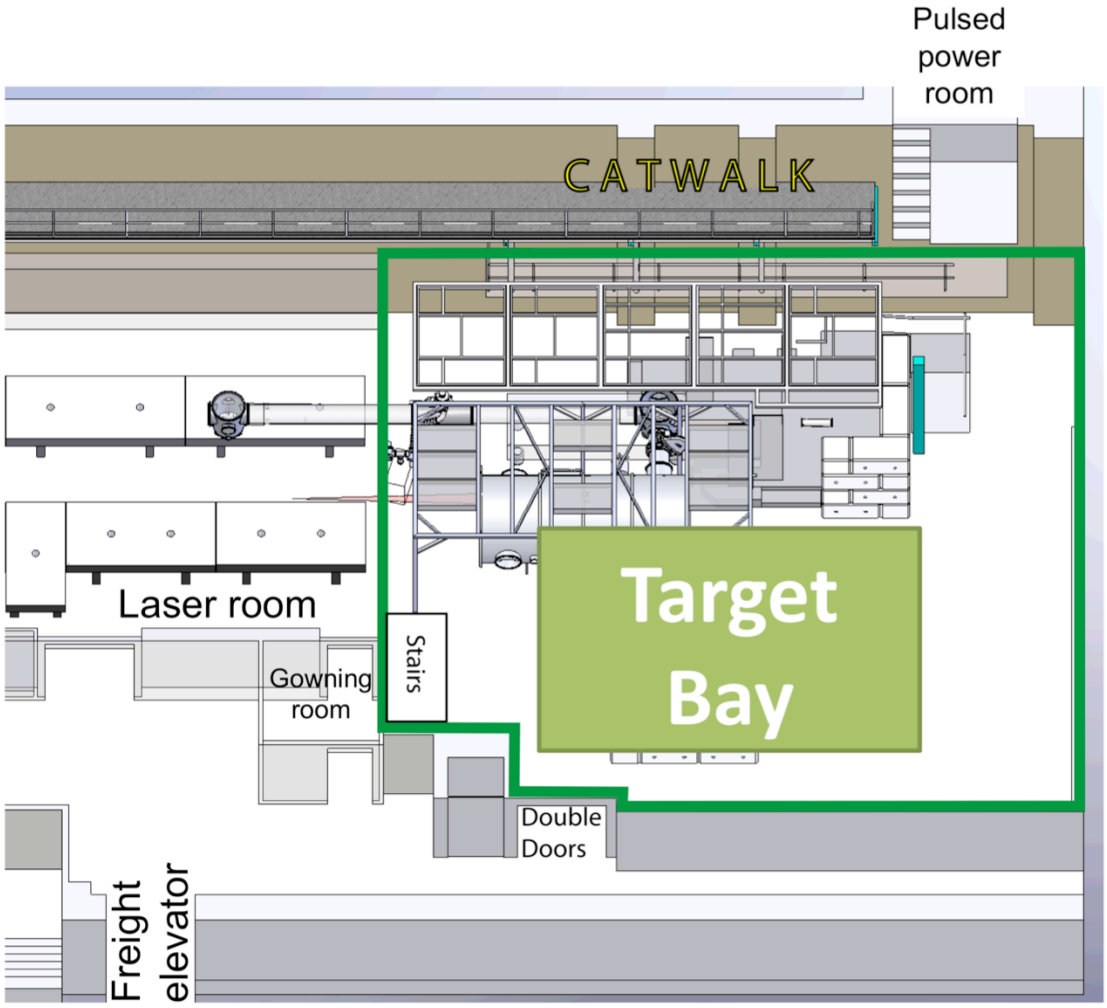

Figure 1 Section of the Texas Petawatt Highbay, with Target Bay outlined in green. This illustration is oriented with the south side on top.

The Target Bay is a controlled accesses area within the Texas Petawatt High Bay that shares its east wall with the Laser Bay (see Figure 2). The various regions within the Target Bay are illustrated in Figure 2, and outlined below. Three cleanroom curtained regions define the Target System Clean Area, the Compressor Cleanroom, and the Laser Diagnostic Area. The Compressor Cleanroom and Diagnostic Area can only be accessed with authorization and guidance of a Laser Operator in accordance with TPW-D-0011. A catwalk overlooks the Target Bay but can only be accessed with authorization and guidance of a Pulsed Power System Operator (pulsed power RI), as described in TPW-D-0012.

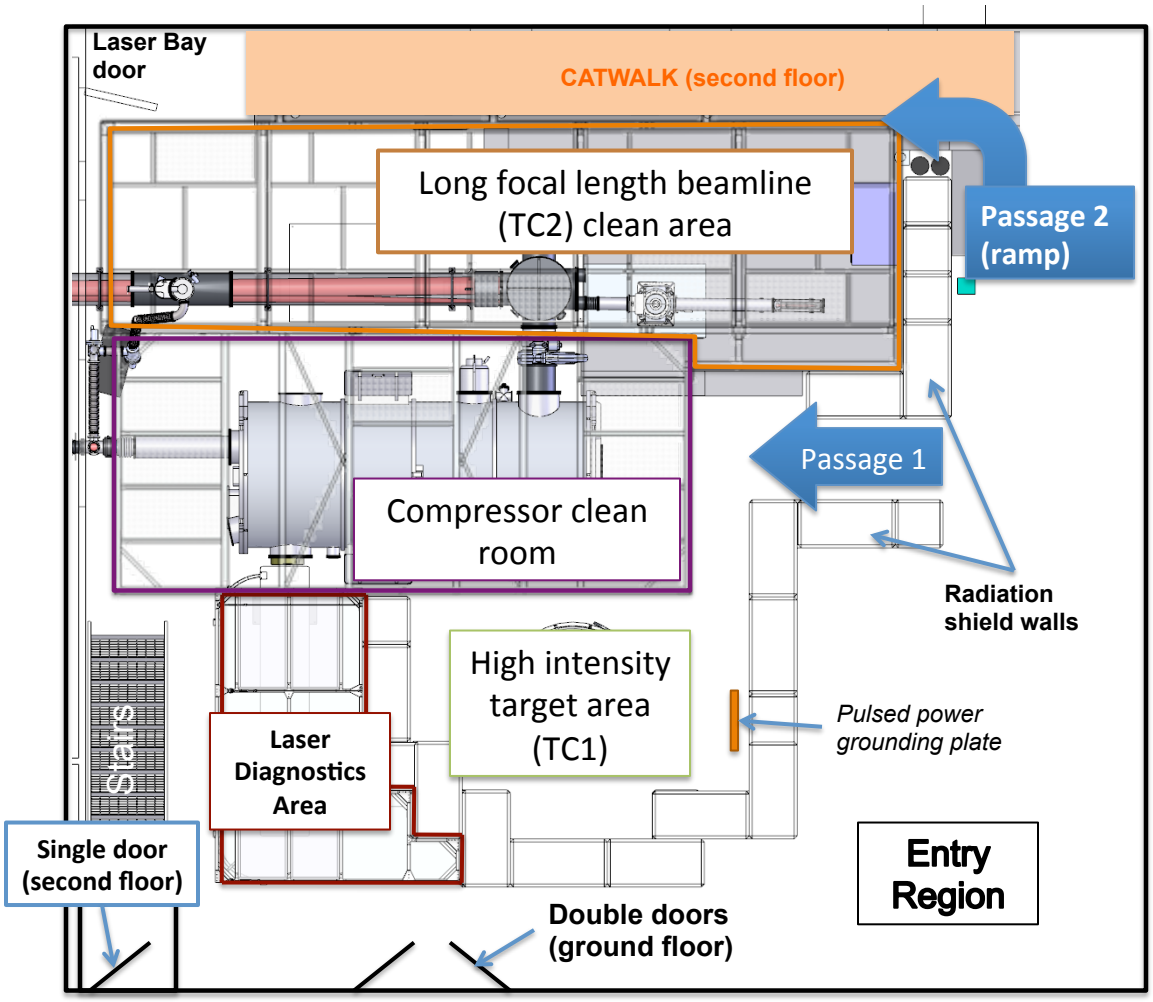

Figure 2 Layout within the Target Bay. Black dashed lines indicate the boundary of the Entry Region. South is on top.

2.1 Entry Region

The main double doors on the first floor open into the Entry Region of the Target Bay. This is the region on the other side of the radiation shield wall from the compressor and target chambers, and outside of any cleanroom or laser curtains. In the Entry Region, the radiation shield wall blocks the direct line of sight to the target chambers or compressor

chambers (although gaps exist at the corners of the bricks). However, it is important to remember that ***any goggle requirements apply equally at all locations within the Target Bay, including the Entry Region***. As described in Section 4.3.4, users will be required to leave the target areas and wait in the North part of the Entry Region while rod shots into the target chamber are charged and fired. As detailed in Section 4.3.5, even the entry region must be evacuated for a full system shot. Note that the stairs are not part of the entry region, so APs shall not enter the Target Bay through the upstairs Single Door during "ROD SHOT" mode until they have established communication with the laser operator (see Section 4.3.4).

2.2 Laser Diagnostics Area

The Laser Diagnostics Area is a clean area enclosed by laser/cleanroom curtains, with the radiation shield wall along one side, as indicated with a red boundary in Figure 2. Access to this area is controlled by Laser Operators, and those inside must follow cleanroom protocol outlined in Section 5 and in TPW-D-0011. Careful passage to TC2 may be permitted through this area.

2.3 Compressor Cleanroom

The Compressor Cleanroom is enclosed by cleanroom curtains and is indicated with a purple boundary in Figure 2. Access to this area is controlled by Laser Operators, and those inside must follow cleanroom protocol outlined in Section 5 and in TPW-D-0011. Slight intrusion into this cleanroom will be allowed for gowned experimentalists working on TC1 when the compressor is under vacuum.

2.4 High F-number beamline clean area (TC2)

The high f-number beamline clean area is indicated by an orange boundary in Figure 2. The high f-number target vessel, or TC2, is in this region. Cleanroom garb requirements depend on the status of the target chambers, as detailed in Section 5. Operation of the vacuum systems connected to the target chambers is restricted to specific authorized personnel, as described in Section 3.1.4. Under certain conditions, a sweep for residual activated nuclei will be performed after a shot before users are allowed access to the chambers. These rules are described in Section 4.4.2.

2.5 High intensity target area (TC1)

Two-story high radiation shield walls tightly enclose the high intensity target chamber, usually referred to as TC1. The target chamber is large enough for a person to partially or fully enter, and appropriate cleanroom garb is required for this, as detailed in Section 5 Operation of the vacuum systems connected to the target chambers is restricted to specific authorized personnel, as described in Section 3.1.4. Under certain conditions, a sweep for residual activated nuclei will be performed after a shot before users are allowed access to the chambers. These rules are described in Section 4.4.2.

2.6 Radiation shield walls

The radiation shield walls are comprised of two-ton concrete bricks designed to shield all surrounding areas from radiation incurred during high-intensity TPW experiments.

These bricks can also act as optical barriers, and separate the Entry Area from the target and compressor chambers. Still, it is important to wear appropriate goggles throughout the entire Target Bay.

2.7 Passages

Passage from the Entry Area to the Target Clean Area (i.e., TC2) is achieved via Passage 1 and Passage 2 in Figure 2. Passage 2 follows a ramp onto raised flooring, while Passage 1 remains at ground level. Passage 1 also leads to the TC1 target area. Because beam height is five feet relative to ground level, the laser operators may restrict access to Passage 1 under certain conditions.

2.8 Engineered Optical Hazard Mitigation

The beam height at the output of the compressor is 5 feet above ground in the target area, which is near eye height for many users. The beam at TC2 is slowly focusing and so stays at dangerous intensities over long distances. Also, the probe beam enters the TC2 target chamber at this beam height. For this reason, raised-access flooring at 1 foot height has been installed in the area immediately around the target chambers of TC2. Flooring panels can bear a load of 1000 lbs per panel and pressures up to 1000 psi. Panels can be moved or altered to allow for equipment that is heavy or needing better stability. Passageway 2 (Figure 2) follows a ramp to the raised flooring while approaching a line of site to the target chamber.

At TC1 the main focus expands quickly, and the probe line enters the target chamber low. However it is important to be aware that the focus of the laser and target for probe beams will be at eye height for most people.

2.9 Regions outside the Target Bay

2.9.1 Pulsed power room (“cave”) and Catwalk

A catwalk extends over the Target Bay and certain experimental diagnostics may be mounted there. The catwalk is accessed from the passageway to the pulsed power room (not shown in Figure 2), and high voltage lines run along it. For this reason, users desiring access to the catwalk must be certified as pulsed power authorized personnel as dictated in the Pulsed Power OSP, document TPW-D-0012. The Pulsed Power Operators (RIs) control access to the catwalk and pulsed power room.

2.9.2 Laser Bay

The Texas Petawatt Laser Bay is a class 100,000 cleanroom (measured at 10,000) containing all of the laser system before the compression stage, a class 100 cleanroom area, and a vacuum chamber containing the f/40 spherical mirror that focuses into the target chamber in the target cleanroom. The spherical mirror chamber has a large lens allowing for imaging of the beam and backscatter from the target. Users desiring unescorted access to the Laser Bay must sign and follow the Laser Bay OSP, TPW-D-0011.

Authorized personnel communicate with operators in the Laser Bay using walkie-talkies, available in the Target Bay, or by calling the laser bay phone (2-2478). Shot communications are conducted over the walkie-talkies only.

2.9.3 Control room

The Texas Petawatt Control Room is located on the second floor, on the north side of the Texas Petawatt High Bay. System shots are coordinated and executed from this room, and personnel will be required to stay in this room, or leave the high bay, during a system shot (see Section 4.3.5).

3 Operators, Authorized Personnel, and Visitors

3.1 Operators

Operators are those who control equipment and access to equipment. They are professional employees of CHEDS with specialized training. Lists of operators and their phone numbers are given in the back of this SOP.

3.1.1 Laser Operators

Laser operators who are authorized to perform work on the Petawatt laser table and in the compressor chamber in the Target Bay. Further information concerning laser operators is given in OSP TPW-D-0011. The designated shot director at any point during an experimental campaign will be one of the laser operators.

3.1.2 Shot Director

The Shot Director is the Laser Operator who coordinates firing of the laser. There is only one Shot Director at any time, and the identity of the Shot Director will be clearly communicated to all facility personnel. Personnel must request authorization for any operational change from the Shot Director. This includes (but is not limited to) the opening of laser blocking gate-valves, releasing of alignment beams, and any change of safety status. The primary duties of the Shot Director are to:

- Start up the laser system.
- Initiate rod shots.
- Pump out and vent the Laser Bay & Compressor Vacuum sytems.
- Bring laser light from the Laser Bay to the Target Bay.
- Initiate system shots.
- Support Users with specific laser requests.

NOTE: A separate OSP provides detailed Laser Operator instructions to perform these duties (TPW-D-0016).

3.1.3 Pulse Power Operators

Pulse Power Operators (RIs) regularly modify, maintain and operate the pulse-power system powering the flashlamps for the main amplifier heads. They also control access

to the catwalk, which is restricted to individuals who have read and signed OSP TPW-D-0012.

3.1.4 Vacuum Operators

Vacuum Operators are qualified to manipulate vacuum controls during regular operation and to produce pumpdown and venting procedures for specific target chamber configurations. **Only users that have been specifically authorized and briefed by a vacuum operator are permitted to operate any vacuum valve or system on their own.** A vacuum operator who wishes to open or close any gate valve that can act to block the laser path must first obtain permission from the Shot Director. Furthermore, all vacuum operations must be coordinated with the appropriate laser operators.

3.1.5 Crane Operators

Crane Operators are qualified to operate the overhead crane.

3.2 Target Bay Authorized Personnel (AP)

Target Bay Authorized Personnel may access the Target Bay under normal laser hazard conditions and perform work in the Target Clean Area. To become authorized personnel, an individual must meet the following requirements:

- Completed the UT laser safety course (OH 304) or equivalent course from their home institution.
- Taken the site-specific hazard communication training module (OH 102), which has been written by the TPW staff
- Completed site-specific safety training with an authorized person and signed completion document.
- Signed the OSP signature form at the end of this document.

3.3 Visiting Researcher Authorized Personnel

Scientists from outside UT who wish to have AP status must first become official Visiting Researchers to the University of Texas. This is an official unpaid position at UT that allows the individual to have a UT ID and also grants access to library facilities. The cost to CHEDS is $100 per activation, and the position typically lasts for 1 year. The process takes between 1 and 2 months to complete, even for renewals. The steps for becoming a visiting researcher are as follows:

1. Obtain a UT EID by visiting http://bealonghorn.utexas.edu/services/signup/eid
2. Identify a senior CHEDS staff member or professor to be your sponsor
3. Complete a background check authorization form for university affiliates, http://www.utexas.edu/hr/forms/background_check_affiliate_em150b.pdf, and forward it to your sponsor and Maria Aguirre (maguirre@austin.utexas.edu)
4. Email your CV to your sponsor and Maria Aguirre. Include your nationality and current place of employment or affiliation along with its location.
5. Your sponsor must provide a 1-3 sentence description your planned research activities at UT.

6. After your information is processed you will receive an offer for unpaid employment signed by your sponsor. Sign this and deliver by email / fax / printout to Maria Aguirre.
7. When your Visiting Researcher status is approved, you can go to the FAC building on campus to pick up an ID card.

Official visiting researchers can become qualified APs like ordinary UT employees so long as their status is current.

Access to the Compressor Cleanroom and Laser Diagnostics area is restricted to APs of the Laser Bay, who have signed TPW-D-0011.

3.4 Short Term Visitors

Non-AP visitors to the lab require escorting by an AP for access to the Target Bay during a laser hazard or to the Target Clean Area. Any group of visitors larger than three people is considered a tour, and their entry requires special permission from the Shot Director. Visitors must be accompanied at all times while they are in the target bay.

4 Hazard modes and communication

This Section describes the major laser and electrical hazards that can be encountered in the Target Bay, and how they are communicated to users.

The Target Bay contains the following hazards.

- **Optical Hazard:** The laser system is a Class IV laser and can cause severe eye damage, skin burns and ignite flammable materials. Other Class III and IV lasers may be employed for a given experiment; laser operators must authorize all abnormal laser hazards.
- **High Voltage Hazard:** The high voltage delivered from the Pulsed Power (see OSP TPW-D-0012) can present a lethal electric shock hazard. The grounding terminal for this system is located in the Target Bay (Figure 2). High voltage power supplies for experimental apparatus also poses an electrical shock risk.
- **Hazardous Materials:** The following solvents are used in the Target Bay: Acetone, Methanol, Isopropyl Alcohol, Ethanol, Nova Clean and Vacuum grease. Details of these hazards can be found in the OSHA MSDS sheets located in the document tray at the entrance to the Laser Bay. The surplus supply of these solvents must be stored in a yellow cabinet specially designed for flammable materials.
- **Radiological hazard:** On-shot radiation levels can exceed maximum permissible exposure near the target chambers. These levels are actively monitored in cooperation with EH&S. Levels outside of the target area have been shown to be safe. Nuclear activation of targets and diagnostics are also monitored by TPW personnel and may require special action, as discussed in Section 4.4.

4.1 Optical hazard

Eye hazards present in the laboratory are all Class IV lasers. The wavelength, energy and pulse duration are different depending on the subsystem of the laser. Below is a list of subsystem performance specifications and Figure 3 depicting the laser table with the subsystems highlighted. In Figure 4 is shown the path of the probe beam, which is not confined to the vacuum vessels.

- OPA: **>500 mJ @ 1057 nm**
- Probe beam line: **10 mJ @1057 nm**
- Rod Amplifier**: 20 J @ 1057 nm single shot**
- Main Amplifier Retro**: 75 J @ 1057 nm single shot**
- Main Amplifier Output**: 200 J @ 1057 nm single shot**

Note: All Laser Bay subsystems described above are Class IV lasers. Avoid eye or skin exposure to direct or scattered radiation.

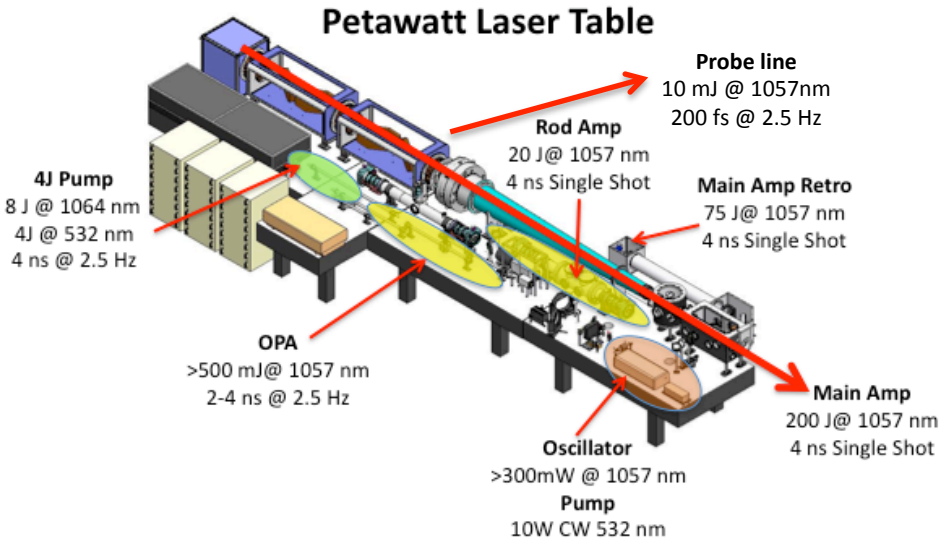

Figure 3 Laser light levels at different locations of the laser table. The laser table is located in the laser bay and fires into the target bay along the main amp line.

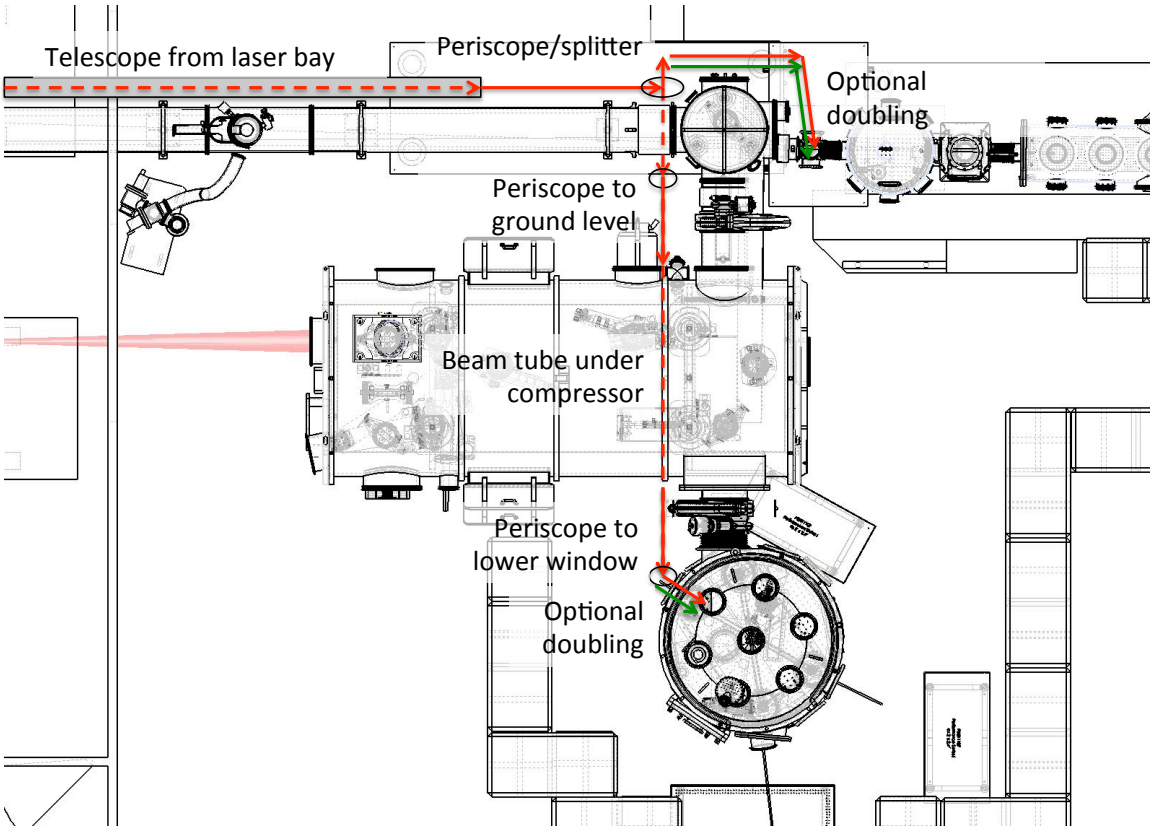

Figure 4 Path of probe line in target bay. The probe line constitutes a Class IV laser hazard and all users must be aware of its path, and whether it is being frequency doubled.

4.1.1 Class IV lasers

By definition, a class IV laser can burn the skin, in addition to potentially devastating and permanent eye damage as a result of direct or diffuse beam viewing. These lasers may ignite combustible materials, and thus may represent a fire risk. Class IV lasers must be equipped with a key switch and a safety interlock. Many industrial, scientific, military, and medical lasers are in this category.

4.1.2 Class IIIb / IIIR lasers

Any CW laser that is below the level of Class IV but exceeds 5 mW in power is considered class IIIb / IIIR. Viewing of diffuse laser light is not harmful to the eye but direct or specularly reflected beam light can cause permanent eye damage. For this reason:

1. *The laser operator on duty must be aware of and explicitly approve the use of the IIIb laser, making note of the wavelength, power, and period of use of the laser, and*
2. *The approved laser may only be used inside the target bay or laser bay, and only when the target bay is in a laser hazard mode.*

4.1.3 Class IIIa and below

Laser pointers and most HeNe lasers tend to fall into this category. It is possible, particularly with red HeNe lasers, that brown goggles offer no protection against the laser wavelength. However the use of the HeNe laser will be deemed acceptable following these guidelines:

1. *Beam paths must be well defined and controlled, using horizontal paths whenever possible and clearly defining the end target of the laser beam path*
2. *All stray reflections from windows and transmissions through windows must be blocked*
3. *The laser must not be left on unattended*

With explicit approval from a laser operator, a Class IIIb CW laser may be reduced to class IIIa and used in this manner by rigidly attaching an filter at the exit of the laser such that most of the power is blocked and absorbed. This filter must be clearly labeled with warnings that prevent users from removing the filter while the laser is on.

4.1.4 Protective eyewear

The goggles made available at the goggle stations are appropriate for all hazardous wavelengths covered in this document, and therefore all wavelengths permitted in the target bay above class IIIa. The goggle stations are located at the outside of the doors to the Target Bay. The goggles are available in several styles depending on whether over-glasses protection is required. Laser Operators, reachable by phone, can help locate the required goggle style if it is not available at one of these stations.

4.2 Hazard Level Communication

All APs must know how to determine what laser eye hazards are present in the Target Bay. The Laser Operator will alert users in the Target Bay to imminent changes in the status level. Interlock Status Panels (ISPs) and Laser Warning Lights continuously indicate hazard levels, which APs check before entering the bay and periodically while in the bay. P.A. system announcements will help AP's determine when there is a change in the laser hazard status.

4.2.1 Laser Warning Lights

There are Laser Warning Lights at both Target Bay entrances, the double-door ground floor and single-door upper floor (Figure 2). These warning lights are shown in Figure 5 and Figure 6. **The laser warning lights are connected to the ISP status, except during maintenance of the ISP panel (see section 4.2.2).**

If the Hazard Warning Light is on at the entrance of the Target Bay, laser goggles must be worn upon entering the Target Bay.

The Laser Warning Lights are automatically coordinated with the Interlock Status Panels, described below. If (due to a malfunction) the Laser Warning lights and ISPs disagree about the hazard level in the Target Bay, brown goggles must be worn in the Target Bay. APs should alert a Laser Operator to such a discrepancy.

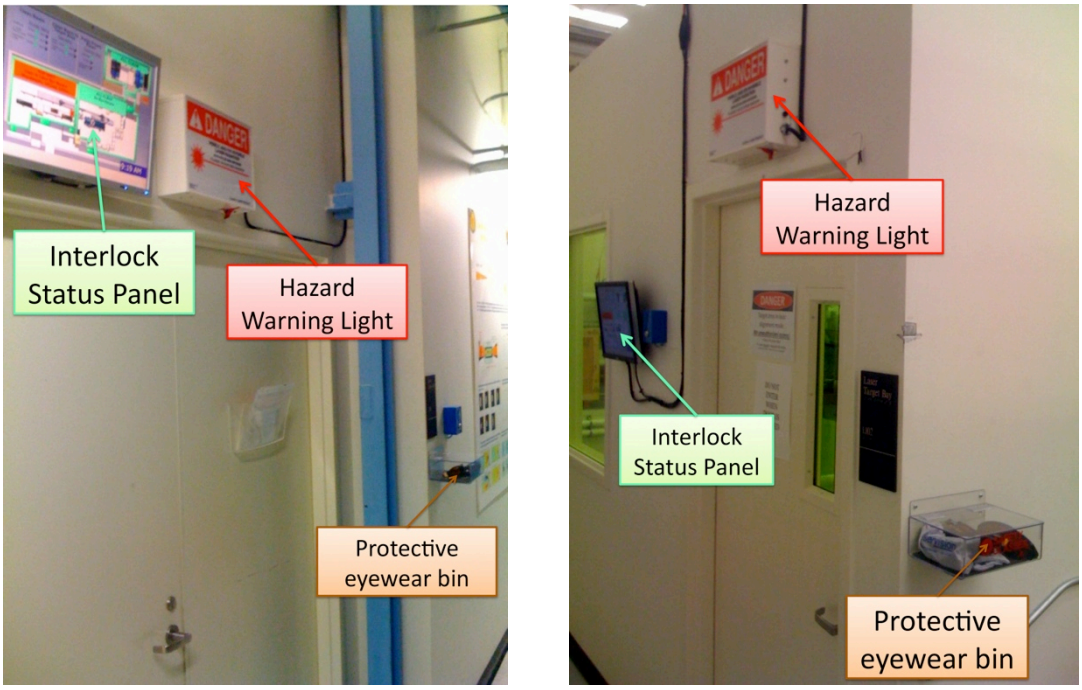

Figure 5 Locations of Laser Warning Lights, ISPs, and protective eyewear bins at the two entrances to the Target Bay: the first floor double doors (left), and the second floor door (right).

Figure 6 Hazard Warning Light in Target Bay visible from Target Clean Area

4.2.2 Interlock Status Panels

Detailed information about the laser status is displayed on monitors located around the lab called Interlock Status Panels (ISPs). Each ISP shows the same image, indicating what hazards are present in the Target Bay, Laser Bay, and Pulsed Power room. See OSP-TPW-D-0012 Pulsed Power and TPW-D-0011 Laser Bay for descriptions of the ISP for those areas. The locations of the ISP panels are indicated in Figure 7

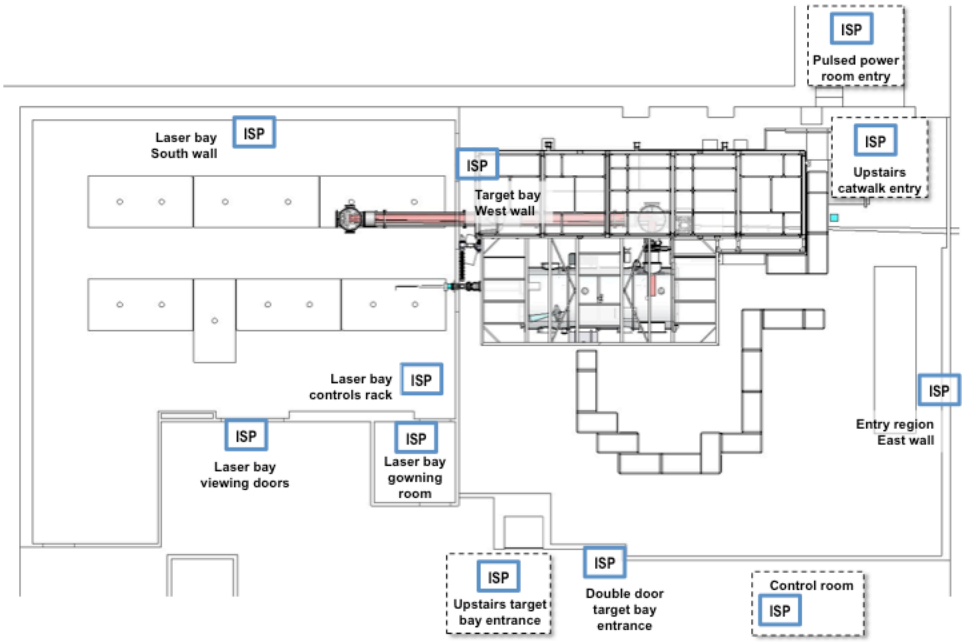

Figure 7 Interlock status panels (ISP) are placed at various locations around the lab. Each status panel screen is identical, and communicates hazards at all locations within the lab.

The Target Bay has 6 standard hazard modes: ALL CLEAR, WARM UP, LASER ON, ROD SHOT, ROD SHOT Charging, and NO ENTRY (interlocked for system shot or pulsed power firing). These status levels and their indication on the ISPs are described in section 4.3.

Figure 8 shows an ISP for the condition when all three areas are safe with respect to laser and electrical hazard. The ISP depicts the high bay with colored lines outlining each of the Target Bay, Laser Bay, and Pulsed Power Room, with text inside each area indicating the hazard level.

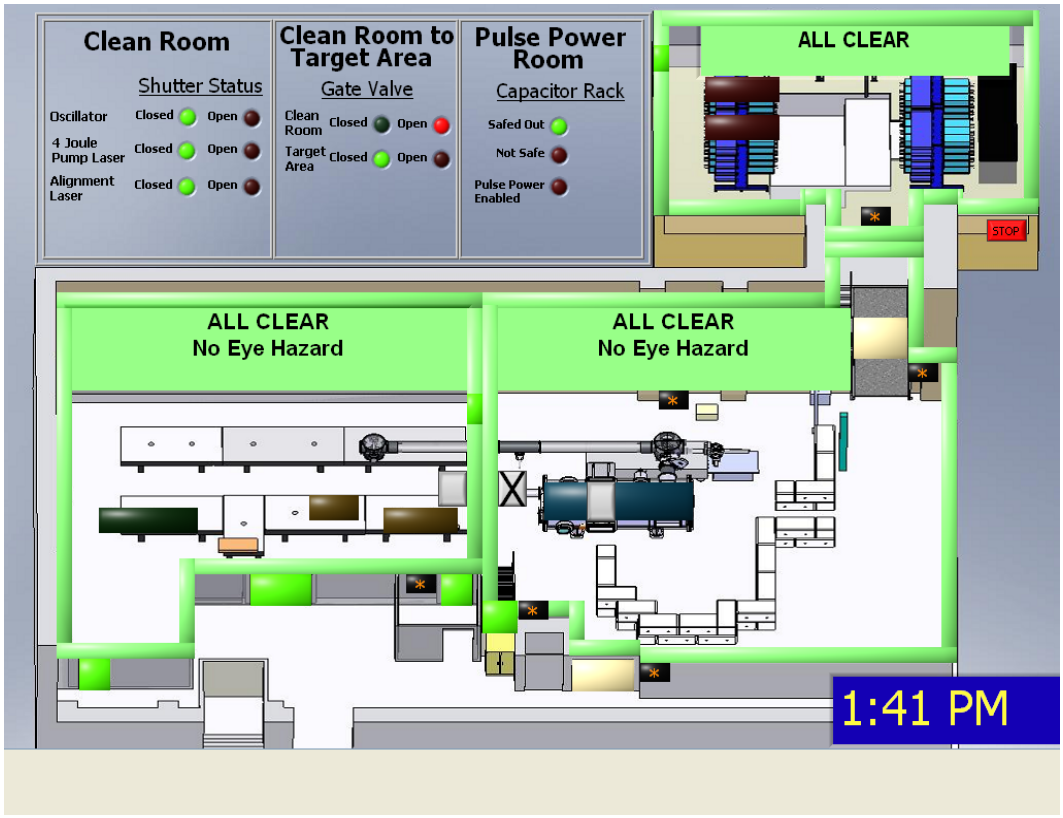

Figure 8: ISP for all three areas in "ALL CLEAR"

In the upper left corner of the ISP screen (see Figure 8) are indicators of system status. The first column ("Clean Room") refers to the Laser Bay, and indicates the status of shutters on three main lasers: the oscillator, the 4 Joule pump laser of the OPA, and the CW alignment laser (see TPW-D-0011 for more information).

In the second column ("Clean room to target area") is shown the light blocking status of the two gate valves between the Laser Bay and Target Bay. When closed, the target area gate valve blocks the laser from passing into the target bay via the compressor. Because the clean room gate valve contains a window and thus does not block laser light, it is always indicated as open on the ISP, regardless of the physical gate valve position. These gate valves are indicated in the image as well, as boxes on either side of the wall between the laser bay and Target Bay. In Figure 8 the "X" in the target side gate valve box indicates that the gate valve is closed. The target area gate valve is gray, indicating that no laser light is hitting it. If laser light is hitting the gate valve it will be shown as red.

The third column in the upper left of the ISP ("Pulse Power Room") shows the status of the capacitor rack. For more information, consult TPW-D-0012.

The status of each Laser Warning Light is detected and shown on the ISP screens at its location by a box that is black for off and white for on. The ISP controls power to the lights and this feedback helps ensure that the lights are functioning properly.

4.2.3 Public Announcement (PA) System

Because the size of the Texas Petawatt precludes direct line of sight supervision of users by laser operators, a PA system is used within the Target Bay to assist in alerting APs to changes in the laser status, and is also occasionally used for paging individuals.

The PA system is tied to speakers (Figure 9) distributed through the target bay, catwalk, and pulsed power room ("cave"). The volume of the speakers in the target bay is set separately from those in other regions and has been tested for audibility throughout.

Figure 9: Two of the PA system speakers located in the target bay

A summary of common announcements is given in section 4.3.6.

4.3 Target area laser hazard modes

These modes refer to the Hazard Modes indicated in the Target Bay section **only**, of the ISPs.

4.3.1 ALL CLEAR

"ALL CLEAR" indicates that there are no laser or pulse-power electrical hazards in the Target Bay. If the ISP says "ALL CLEAR" **and the Hazard Warning Light is off**, anyone can go into the non-cleanroom areas of the Target Bay. On the ISP screens below, the Target Bay depiction is outlined in green. The Target Bay may be in "ALL CLEAR" mode even if the laser is warming up or on in the Laser Bay (Figure 10 and Figure 11). As described above, the two gate valves between the Laser Bay and Target Bay can serve to block the normal path of the laser. Figure 11 shows these two gate valves closed (a closed valve is indicated by an "X" over it). One of the gate valves is colored red, indicating that laser light is hitting that gate valve, and that opening it would let the laser light through to the second gate valve.

Before introducing laser hazard into the Target Bay, the Shot Director will announce the upcoming change over the P.A. system (see section 4.3.6) and change the ISP such that LASER ON mode is displayed over the Target Bay on the ISP (Figure 13). The Shot Director will then perform a sweep to ensure that everyone in the Target Bay is wearing goggles prior to actually introducing a laser hazard (see TPW-D-0016). **Do not wait for the sweep: as soon as you hear the announcement or see an ISP screen indicating a LASER ON status for the Target Bay, acquire and don brown laser goggles.**

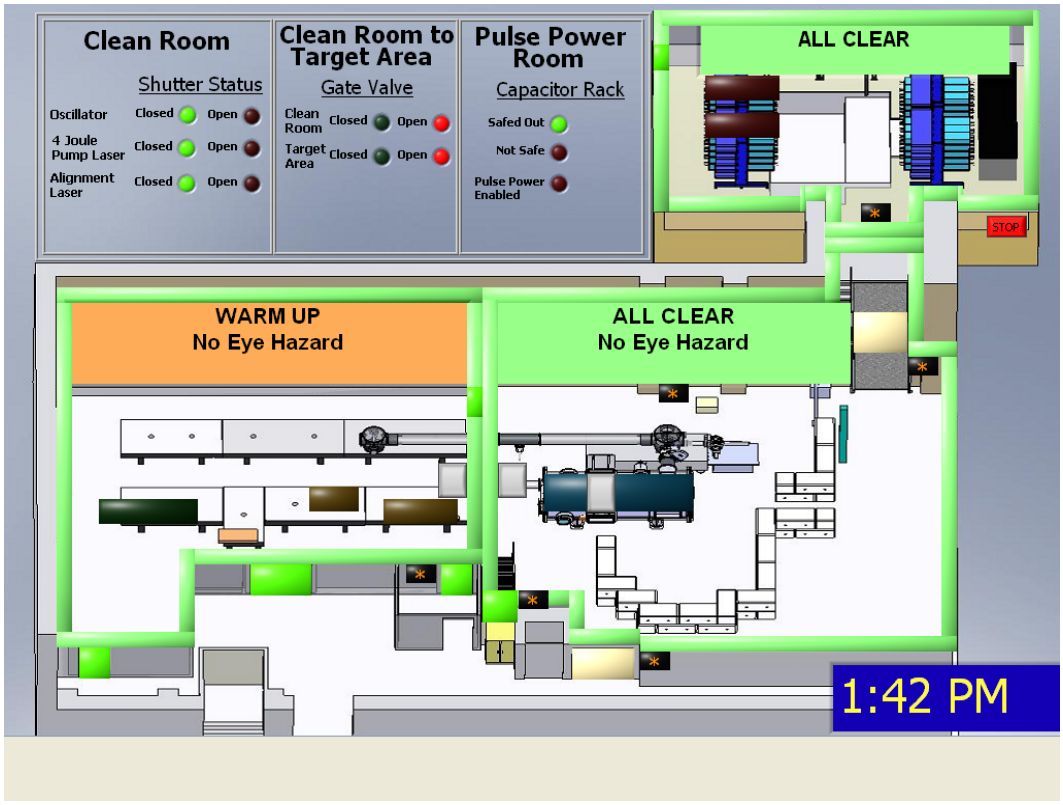

Figure 10 ALL CLEAR in Target Bay while Laser Bay is in WARM UP mode

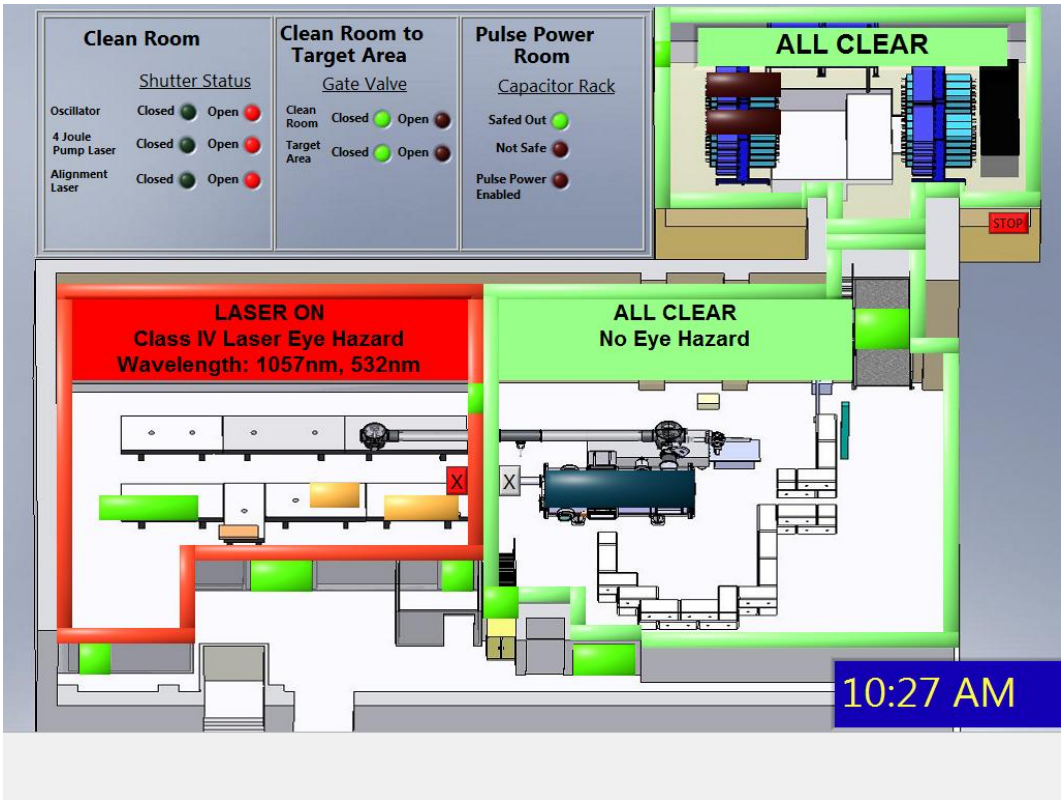

Figure 11: ALL CLEAR in Target Bay while a Laser Bay hazard exists

4.3.2 LASER ON

During "LASER ON" mode in the Target Bay, **all personnel are to wear the laser safety goggles.** When entering the Target Bay, assume there is an optical hazard at the target chamber, until learned otherwise. In this mode, the Target Bay is outlined in Red on the ISP screens (Figure 12 and Figure 13). **When entering the Target Bay in this mode, always close securely the door behind you.**

The ISPs display the "LASER ON" mode in two possible ways, which may change from one to the other without warning (shown in Figure 12 and Figure 13):

- **Gate Valves Open:** An OPA or alignment laser eye hazard exists in the Target Bay. This is because both gate valves at the wall separating the Laser and Target Bays are open (shown in Figure 12). When these gate valves are open, the hazard status of the Target Bay is automatically set to that of the Laser Bay. The compressor chamber will blink, indicating that laser light is entering it. **In this configuration, it is possible that the beam dump in the compressor chamber is either open or closed.** The beam dump status is indicated on the ISP by a box inside the compressor chamber, which displays an X when the beam dump is closed. However, since the beam dump state may be changed without warning, users should always assume a laser hazard within the target chamber.
- **Gate Valves Closed:** OPA or alignment laser eye hazard will be present intermittently and without warning. An ISP screen for this scenario is shown in Figure 13. This means that the gate valves may be opened or closed without

warning or that the door between the Laser Bay and Target Bay may be opened intermittently. The gate valve status is provided only as additional information, and LASER ON mode should be treated no differently when the gate valves are closed: u**sers must keep their brown goggles on at all times in LASER ON mode.**

When switching the Target Bay to "LASER ON" mode from the "ALL CLEAR" mode, the Shot Director will change the ISP status indication to "LASER ON", make an announcement over the PA, and then perform a sweep of the Target Bay and, if they were not already in restricted mode, the pulsed power room and catwalk (see TPW-D-0016). If they are not already active, the laser operator will engage the locks to the target bay. These locks can be operated using authorized UT ID cards, or separately provided key cards.

A laser operator will always perform a sweep of the Target Bay prior to actually introducing hazardous light, but users should not wait for the sweep to find and put on goggles. Goggles should always be worn when the ISP indicates a laser hazard.

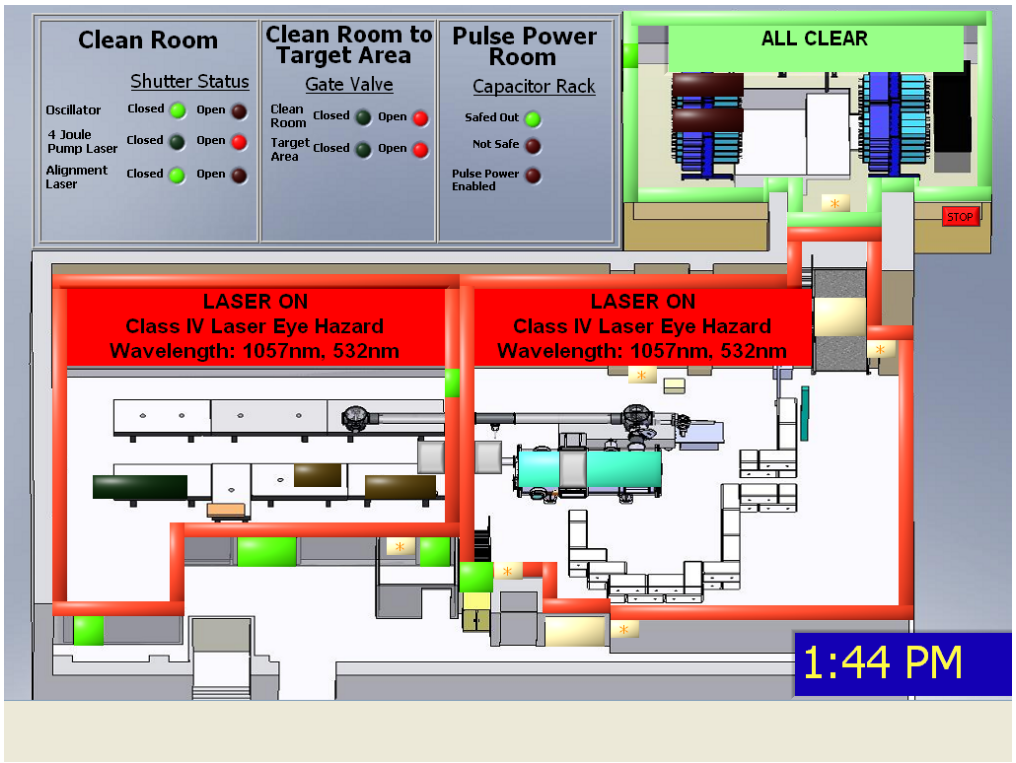

Figure 12: A laser hazard exists in the Target Bay, with gate valves open allowing light into the compressor chamber and possibly the target chamber. Brown goggles must be worn everywhere inside the Target Bay. The compressor graphic is blinking.

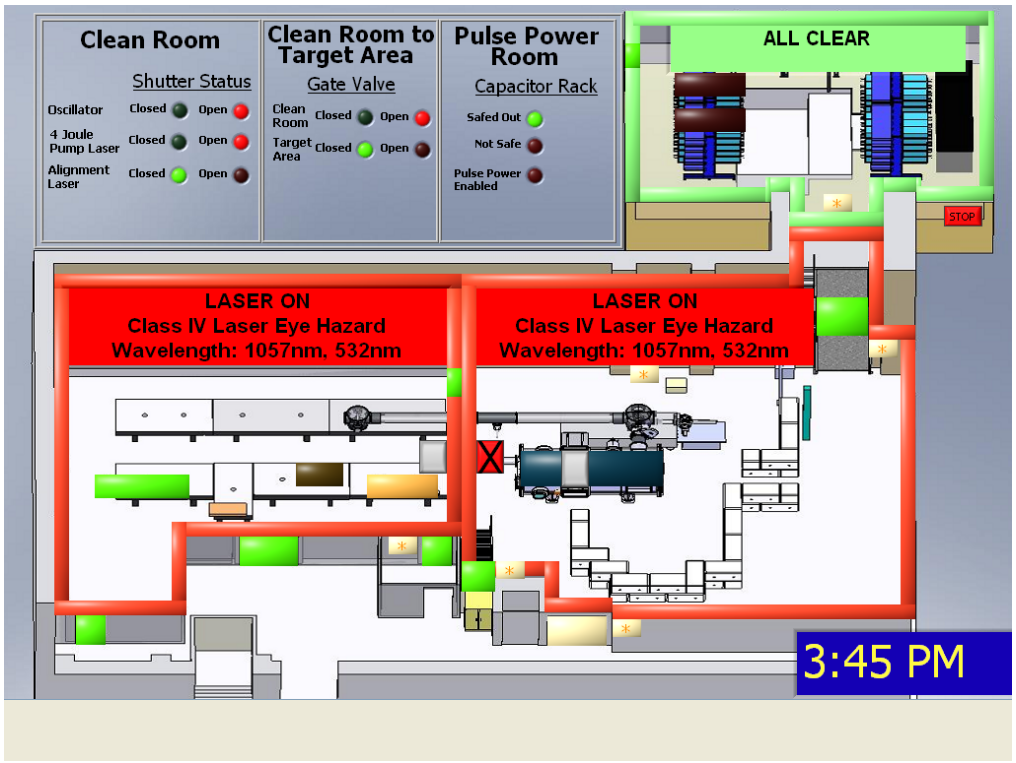

Figure 13 Laser hazard for Target Bay when the gate valve on the Target Bay side is closed. The compressor chamber is not blinking.

4.3.3 WARM UP

During WARM UP of the laser the Target Bay may be open to the Laser Bay, causing both regions to be in WARM UP mode. In this mode, shown in Figure 14, there is no eye hazard but the Laser Operators do intend to introduce a laser hazard soon. Before the laser hazard is introduced, a Laser Operator will make an announcement over the PA system and perform a sweep of the Target Bay to alert users of the change. **If you hear an announcement while the Target Bay is in WARM UP mode you should immediately acquire and don brown laser goggles.**

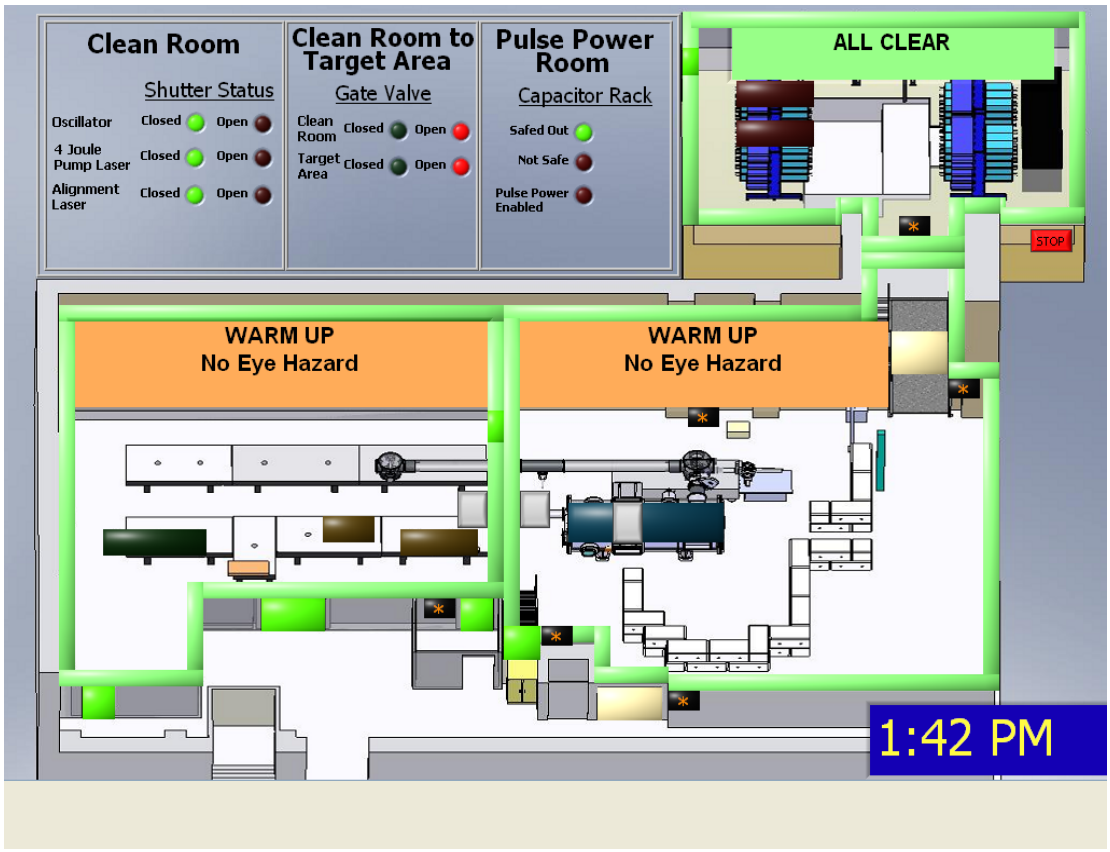

Figure 14 Laser and Target Bay in WARM UP mode.

In switching the Target Bay from WARM UP to LASER ON mode, an automated countdown of 20 seconds is initiated before the laser hazard is introduced (opening the shutter to the oscillator; see TPW-D-0016). This is shown in Figure 15. During this time, the 20-second countdown will be displayed on the ISP screen. At the end of the countdown, the Target Bay will then be in LASER ON mode. Everyone in the Target Bay should be wearing brown goggles by then. *However, as an added precaution the shot director will sweep the target area prior to actually introducing laser light.*

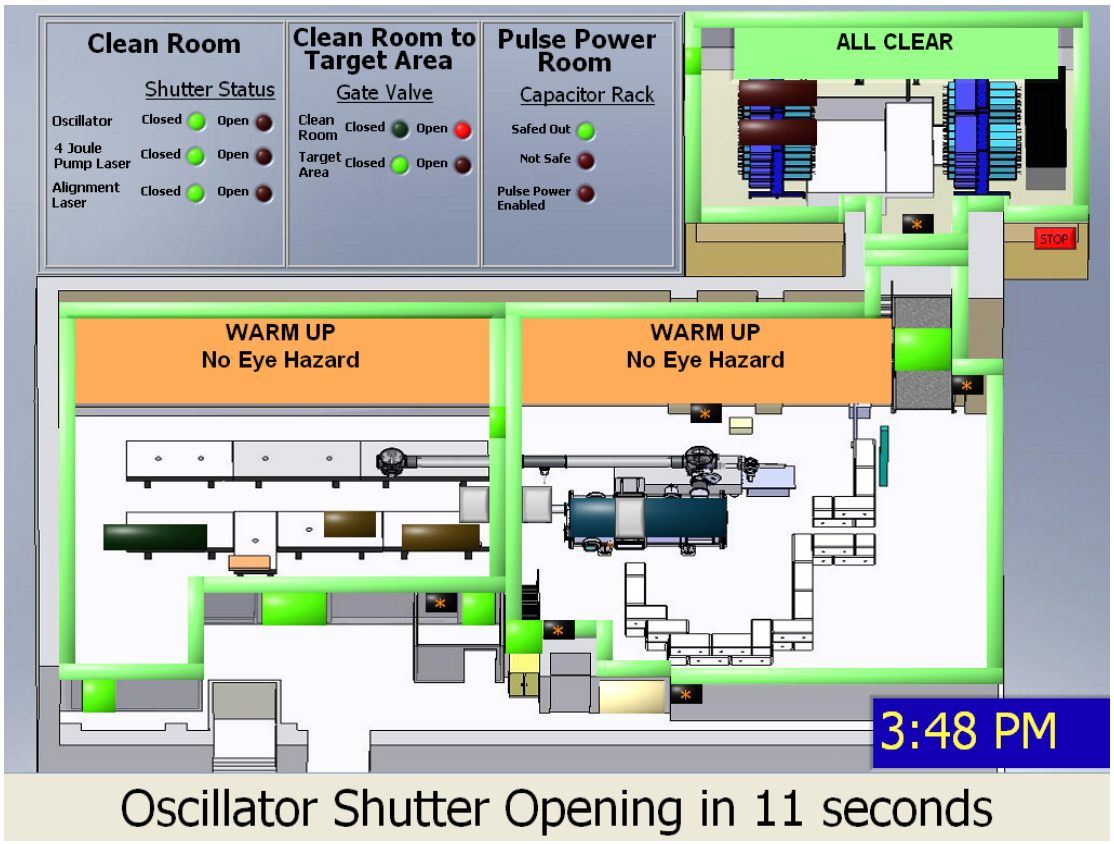

Figure 15 Countdown to LASER ON mode. At the end of the countdown, the Target Bay will be in LASER ON mode.

4.3.4 ROD SHOT

Rod shots are higher energy laser pulses that can be fired about every 15 minutes, with an energy of up to 20 Joules in a pulse. This light is 100 times brighter than the OPA pulses, and so additional precautions are taken within the Target Bay for rod shots. When preparing for a series of rod shots while the hazard levels of the Target Bay and Laser Bay are linked, the Shot Director will change ISP status to ROD SHOT and sweep the Target Bay to alert those inside of the change. ROD SHOT laser hazard mode is indicated by a red outline and text on the Target Bay image on the ISP screens (Figure 16). It is typical for Rod Shot mode to be maintained throughout the day when system shots are to be fired.

When the target bay is in "ROD SHOT" mode, **all personnel therein are to wear the laser safety goggles.** When entering the Target Bay, assume there is an optical hazard at the target chamber, until learned otherwise. When switching the Target Bay to this mode from the LASER ON mode, the Shot Director will announce the change of status and instruct those in the target area to make contact with the control room or laser bay (TPW-D-0016). As with "LASER ON" mode, the entry double-doors and the single upper level door to the Target Bay will be locked. **When entering the Target Bay in this mode, always securely close the door behind you.**

Before proceeding beyond the entry region (Figure 2) in ROD SHOT mode, an AP must have established a line of communication to a Laser Operator either through a walkie-talkie/phone, or through another AP who is already communicating with a Laser Operator. As always, visitors must stay with their AP guide.

- **APs who have *not* established a line of communication must stay in the Target Bay Entry Region, outside the concrete bricks (Figure 2). Further, they may not enter through the 2nd floor stairwell.**
- **If a line of communication *is* made and rod-shot charging for a shot into a target chamber is not imminent, one can enter the target chamber area. "Line of communication" implies awareness of the shot director of your presence in the target bay and frequent phone calls or radio contact.**

As in the LASER ON mode, the laser hazard may be introduced either through the compressor, or through the door between the Laser and Target bays. Section 4.3.2 details how to determine where the laser hazard may be introduced.

Whenever a rod shot is to be fired, the laser operator will make an announcement that indicates whether the rod shot will terminate in the laser bay, the compressor beam dump, or a target chamber. In all cases, those working in the target area will be requested to make contact with the laser operator. In the case of a rod shot into a target chamber, everyone in the target bay will be required to wait in the North part of the entry region. The laser operator may optionally allow work to continue at the target chambers if the rod shot is being fired into the beam dump, or if it terminates in the laser bay.

When contact with the target bay has been made and the target chambers are confirmed as cleared, if necessary, the shot director will announce the start of charging and the ISP screen will show "ROD SHOT (Charging)" (Figure 17). The charge sequence takes about 10 seconds. The shot director will announce the firing of the shot, and the discharging of the rod amp capacitors should be audible.

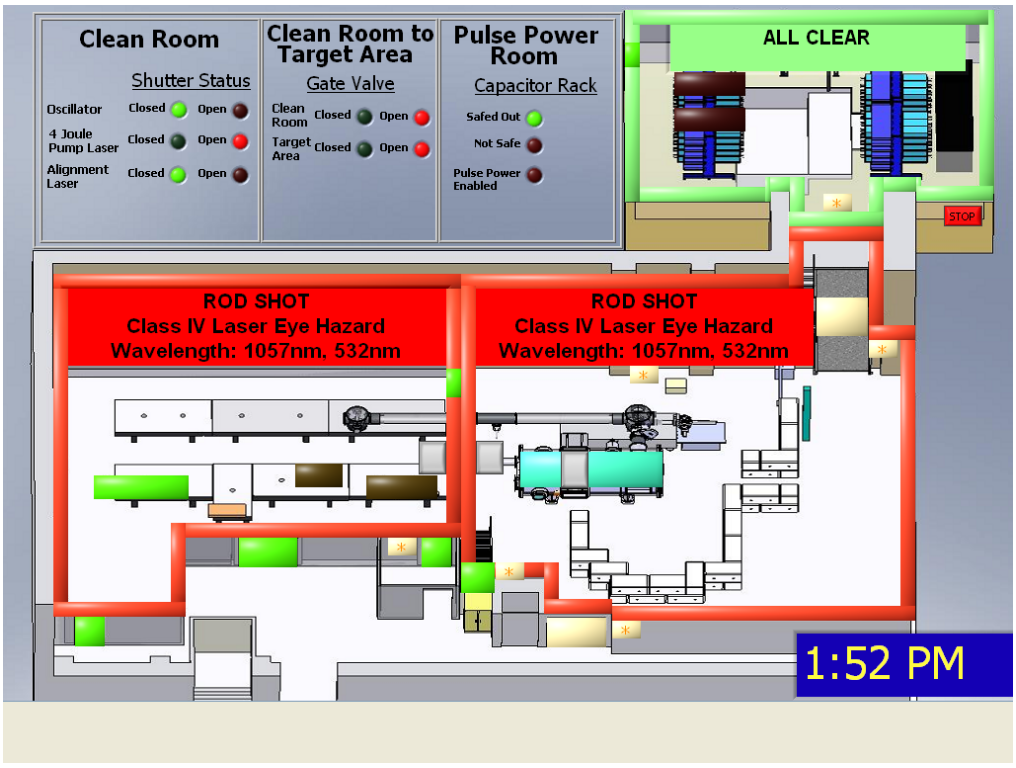

Figure 16: "ROD SHOT" mode. Brown goggles must be worn everywhere inside the Target Bay. Additionally, a line of communication with Shot Director (see text) must be established before work within line of sight of the target chambers.

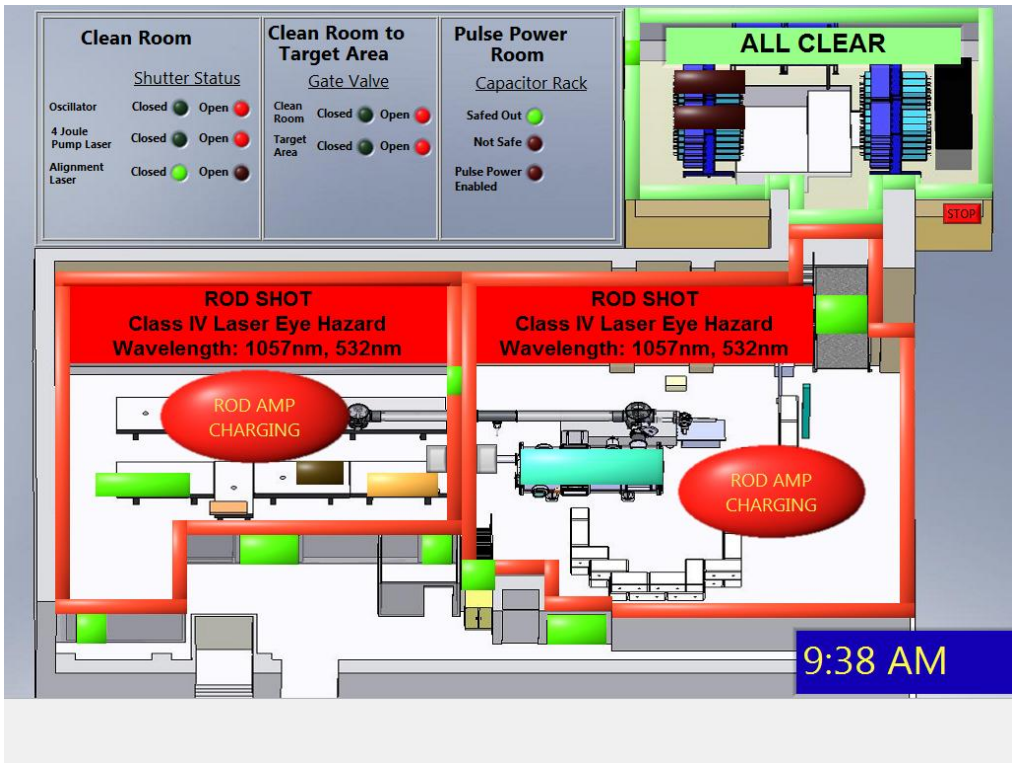

Figure 17: Rod Amp Charging. Users in the Target Bay must remain in the Entry Region, and are in radio contact with the Shot Director.

4.3.5 NO ENTRY

During a system shot, radiation hazards and lethal electrical hazards can be present in the Target Bay. Also, full pulsed power discharge without a laser shot presents the same lethal electrical hazard. For this reason, **NO ONE is allowed to remain in the Target Bay during a system shot or discharge of the pulsed power**. Prior to a pulsed power discharge, the Shot Director will evacuate the Laser Bay, Target Bay, and Pulsed Power Room and set the system interlocks. Setting the interlocks turns the ISP door indicators to red, as seen in Figure 18. Opening a door that is marked red will reset the interlocks and abort the shot. Except in an emergency, do not go in through a red marked door, and stay out of the Target Bay if *any* of the doors are marked red.

Users shall proceed to the control room during a system shot, or leave the high bay. The Shot Director will execute the charging and firing of the system shot from the control room. The PA system will be used extensively during a system shot.

After a system shot is executed, the system will return to "ROD SHOT" mode, as indicated on the ISPs.

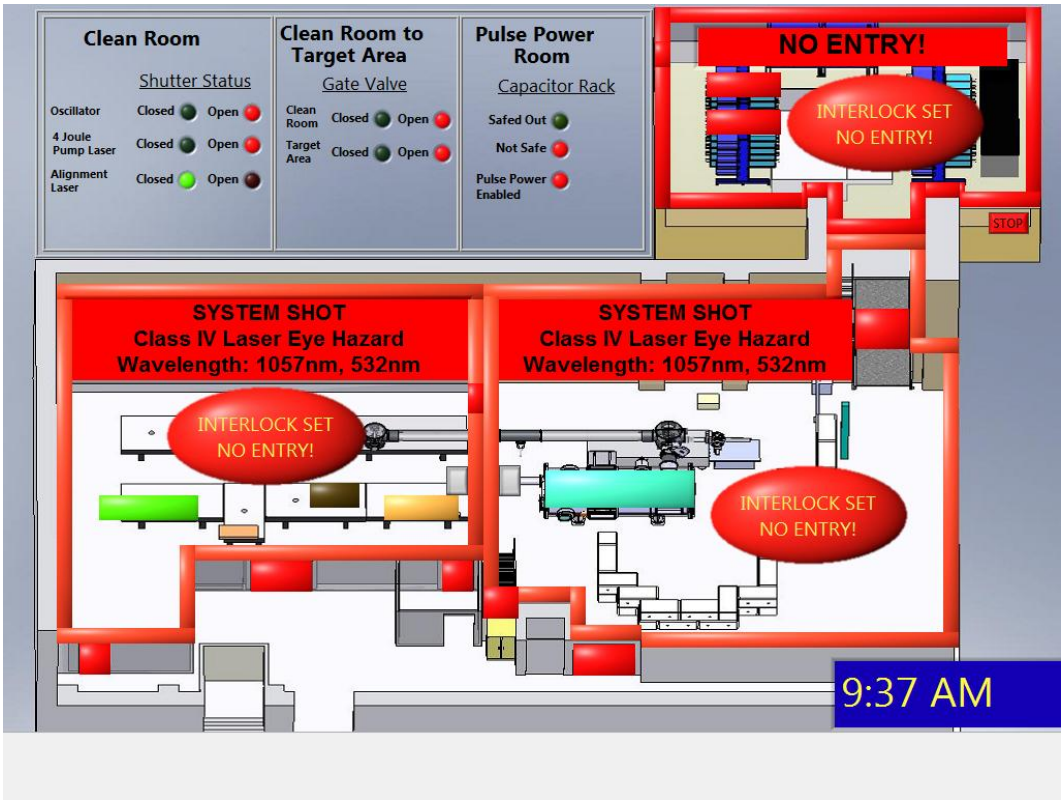

Figure 18: ISP for system shot preparation. Opening any of the doors indicated in red will crash the interlocks and stop the shot cycle. No one is permitted in the Laser Bay, Target Bay or Pulse Power Room under these conditions. Users should proceed to the control room or leave the High Bay.

4.3.6 Summary of announcements for changing laser safety state

The laser operator will use the PA system to make announcements about changes to the laser safety status, which can be done from the control room or the laser bay. The most common alerts are listed below, although the exact wording may vary depending on the laser operator:

- **Laser switching from "All Clear" to "Warm Up" mode:** "Attention, we are entering Warm Up mode. Please carry your goggles with you. Until further notice there will be no laser hazard."
- **Laser switching from "All Clear" or "Warmup" to "Laser On" mode, only in the laser bay:** "Attention, we are preparing to introduce a laser hazard into the laser bay. The target bay is isolated and will remain in 'all clear' mode."
- **Laser switching from "All Clear" or "Warm Up" to "Laser On" mode in the target bay:** "Attention, we are preparing to introduce a laser hazard in the target bay (and laser bay). All personnel in the target bay must now wear laser protective eyewear or else leave the target bay (or laser bay). A sweep of the target bay will follow." [At this time the ISP screen changes to show laser on mode]
- **Laser switching from "Laser On" to "Rod Shot" mode: "**Attention, we are entering Rod Shot mode. If you intend to work near the target chambers, you must establish contact with the laser operator. A sweep of the target bay will be performed shortly."
- **Preparing for rod shot into a target chamber:** "Attention we are preparing for a rod shot in to target chamber (1 or 2). All personnel in the target bay please make contact with the laser operator at this time."
- **Preparing for rod shot into compressor beam dump:** "We are preparing a rod shot into the compressor beam dump. Users may continue to work in the target chambers."
- **Firing rod shot:** "Charging for rod shot. (~10 seconds) Firing rod shot. 3…2…1…fire."
- **Laser switching to "Sytem Shot (no entry)" mode:** "Attention: we are preparing for a system shot. An interlock sweep of the target and laser bays will commence shortly. No one will be allowed to remain inside during the shot."
- **After sweep for system shot:** "Attention: the sweep of the target and laser bays is complete and we are now preparing to charge and fire a system shot. No one is allowed in the laser or target bays."
- **Firing shots:** "Charging for a (system) shot (~30 seconds)… firing system shot in 3…2…1…fire."

4.3.7 ISP maintenance

Occasionally the computer system controlling the ISP screens will need to be taken down for maintenance or during a malfunction. During such maintenance a generic message will be posted on the screens by a laser operator (see below). As always, if the message contradicts the laser warning lights, wear brown goggles inside the target area, and alert a laser operator to the discrepancy.

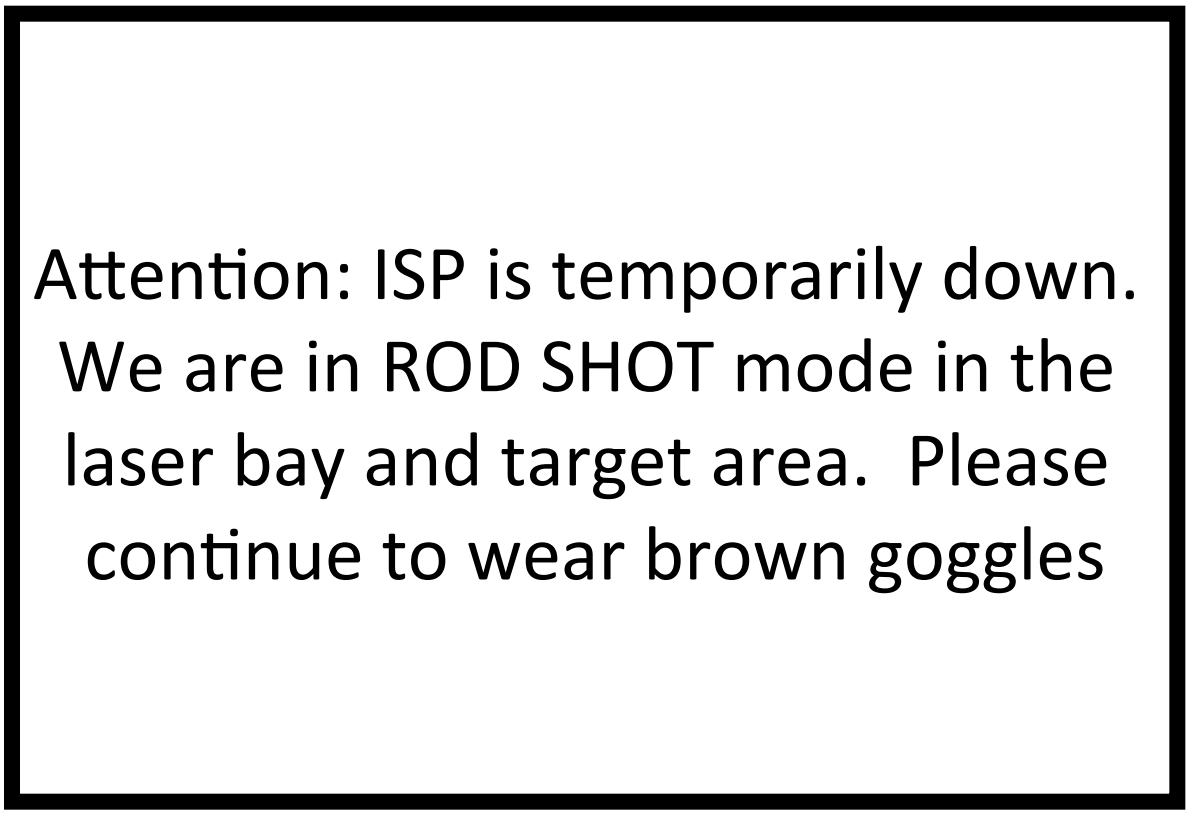

Figure 19 Generic screen for ISP maintenance. Procedurally the ISP screens are only serviced in ALL CLEAR mode. However, users must always wear brown goggles if the Laser Warning Lights are on.

4.4 Radiological hazards

High intensity lasers may accelerate electrons to MeV or even GeV energies. In materials this can lead to dangerous radiation in the form of high energy x-rays or neutrons. The radiological hazard manifests in two parts: on shot, and residual activation.

4.4.1 On-shot radiation

Radiation levels have been monitored using active radiation counters as well as passive area monitors. Active monitoring has determined that all levels of on-shot radiation are safe for users outside of the target area. Passive monitoring is done on a monthly basis using 20 area monitors from Landauer, inc, and is coordinated with EH&S. These have shown that dangerous levels of radiation are typically only present in the laser forward

direction, which is inaccessible during a shot. Illustrations of these data are shown in figures below.

To date, only locations 1 and 10, which are in the laser direction inside the radiation shield walls, have shown significantly above normal radiation dosage levels (up to a few Rem over a full shot run). Records are available on request.

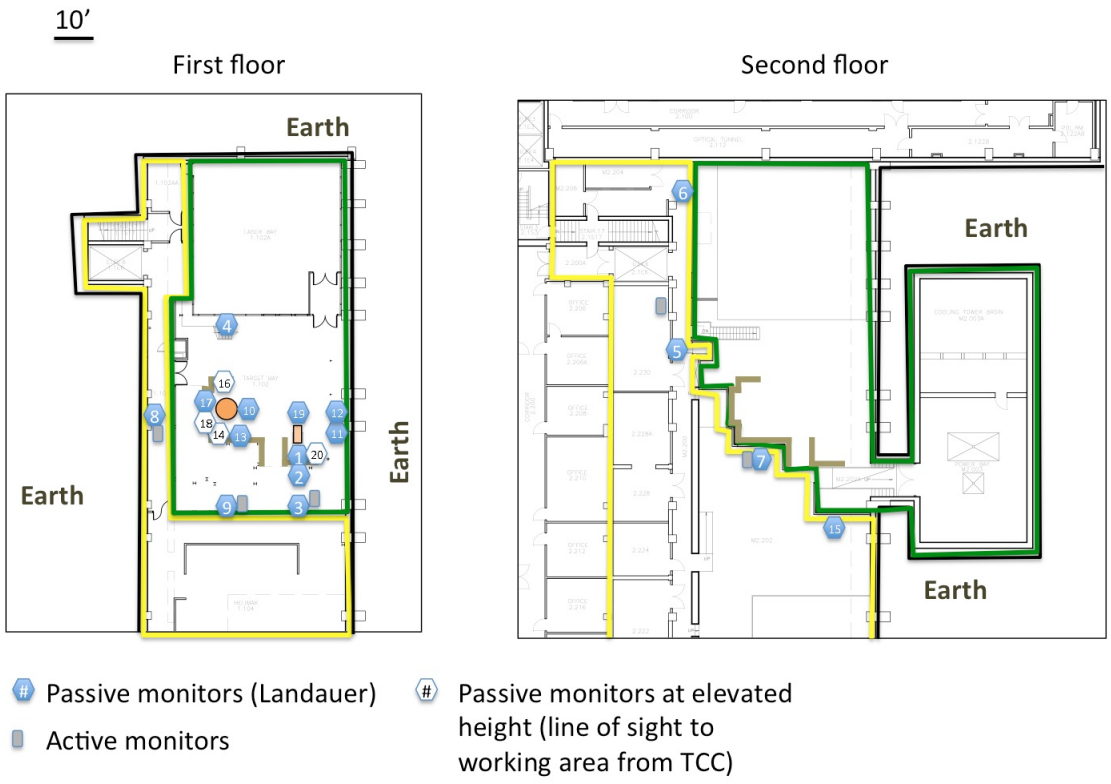

Figure 20 Locations of radiation monitoring. Active monitors have digital readouts and have alarm setpoints. Passive monitors are read out monthly.

4.4.2 Nuclear activation

Several of the TPW staff members and CHEDS graduate students are trained as basic radiological workers, meaning that they are qualified to survey the target chamber after a shot and determine if there are residual radioactive materials that need to be sequestered. Whenever activation of a target or diagnostic is possible, we will use the following procedure:

> Following shots with the potential to activate components, a Texas Petawatt staff member that is trained as a Radiological Worker ("the surveyor") shall be the first to access the target chamber to assess radiological hazards. The nature of the target chamber (vent times) as well as the size of the keep out zones for petawatt shots ensure that this sweep will not occur until ~10 minutes following a shot. If the radiation levels within the chamber are below 3X normal background with the above named survey meter the chamber may be opened for general access. If the radiation levels are above 3X background the surveyor shall mitigate the radiological hazards by either removing the source of the elevated radiation

levels or closing the target chamber and waiting no less than 20 minutes. After 20 minutes the radiological hazards will be reassessed.

HOLD POINT: IF ANY ITEM IS FOUND TO HAVE CONTACT READINGS GREATER THAN 1,000-µrem/hr OR IF THE RADIATION LEVELS SEEM TO BE PERSISTENT, WORK SHALL CEASE AND THE RADIATION SAFETY OFFICER SHALL BE CONTACTED.

The surveyor will proceed systematically. He or she will test the batteries of the survey meter prior to every sweep. Donning nitrile or equivalent gloves, the surveyor will start with the perimeter and region just inside the door to the target chamber and work radially inward towards the target, with special emphasis on any objects in the forward direction from the target. Every measurement of levels detectably above background will be noted in a log, with a top down view of the target chamber noting the location of each reading. For those shot days in which activation 3x above background is found, we will email the daily log to the Radiation Safety Officer at the end of the day

Following consultation with the Radiation Safety Officer, the TPW Radiological Worker may remove activated components from the chamber to reduce radiation levels as long as the radiation levels at contact with the item are less than 1,000 µrem/hr. Removal shall be done using remote methods (e.g. using tongs) and while wearing gloves. The item shall be stored in a labeled shielded container to allow it to decay. Such containers will be approved by the Radiation Safety Officer prior to use, and each use of such a container will be reported immediately. After removal the chamber will be re-monitored to verify all radiological hazards have been identified and removed.

The chamber is swept using a Ludlum Model 2401-P survey meter, which is sensitive to alpha, beta, and gamma radiation.

Figure 21 The survey meter used in the target area for checking for residual activation

If activation is discovered, users must wait for the all-clear from the TPW staff member or graduate student performing the sweep, before accessing the target chamber.

5 Cleanliness protocol

There are no rated cleanroom areas in the target area, but various cleanroom practices are required to minimize the risk of contamination to optics in the vacuum chambers, the compressor chamber, and the laser bay. The following are the cleanroom garb requirements for the target area:

• **Accessing the inside of any vacuum chamber:** Gown, gloves, and hairnet required; facemask for working near a large optic

• **Inside TC2 clean area:** Booties and gown required. Fresh booties and a blue gown must be worn when walking into the laser bay or compressor clean area

• **Outside TC2 clean area**: Gowns worn only for work in TC1 vacuum chamber.

• **Leaving target area by double doors or 2nd floor door:** No gowns permitted. Booties must be discarded

Here are some other guidelines for clean operation within the Target Clean Area:

- **Step on sticky mats with your booties on before entering the target clean area.**
- **Replace sticky mats when they appear at all dirty.**
- **Do not bring wood, cardboard, or excessive amounts of paper into the clean area.**
- **Dust and wipe down items prior to introducing them into the Target Clean Area.**
- **The insides of computers, keyboards, and similar items must be made free of dirt and dust before being used in the Target Clean Area.**

6 Facility contacts

Below is a list of Operators and other important contacts:

6.1 Pulsed Power Room Operators

Marty Ringuette (Primary) 232-2880

Ted Borger 232-2174

Mikael Martinez 471-5648

Erhard Gaul 471-1803

6.2 Laser Operators

Ted Borger 232-2174

Michael Spinks..... 232-2174

Mikael Martinez	471-5648
Erhard Gaul	471-1803
Gilliss Dyer	471-6121

6.3 Vacuum Operators

Gilliss Dyer	471-6121
Erhard Gaul	471-1803

6.4 Crane Operators

Erhard Gaul	471-1803
Ted Borger	232-2174
Gilliss Dyer	471-6121

6.5 Emergency Contacts

UTPD Emergency including fire or medical	471-4441
Gilliss Dyer Cell	512-517-4610
Ted Borger Cell	925-518-6833
Mikael Martinez Cell	512-554-1309
Erhard Gaul Cell	512-784-4583
Mike Donovan Cell	571-438-8956

6.6 Miscellaneous

Maria Aguirre	471-5648
	232-2465
Todd Ditmire	471-3296
	762-5065 C
Aaron Bernstein	471-1940
Mechanical Engineering	232-3533
Laser Bay	232-2478
Control Room	232-2174
Target Bay	471-2559

Signature

This signature section indicates that you have read and understand the procedures and hazards described in this document.

Name	Signature	Date

7 SOP Revision History

Revision History					
Rev	**Description**	**Author**	**Reviewed By**	**Approved By**	**Date**
A	Initial Release	A Bernstein	G. Dyer		March 2009
B	Updated to include warning sounds, WARM UP mode for Target Bay, laser warning lights connection to ISP, ISP service, the audible alert system, and miscellaneous minor changes.	G. Dyer	A. Bernstein		September 2009
C	Clarified information about the P.A. system (renamed from audible alert), made some recommended changes for clarity, changed some language about vacuum operation and cleanroom practices, added information on class IIIR and IIIb lasers added a radiological section, and fixed some typos.	G. Dyer	M. Donovan	G. Dyer	October 2012