Jefferson Lab
Thomas Jefferson National Accelerator Facility

Laser Operational Safety Procedure (LOSP) Form

(See ES&H Manual Chapter 6410 Appendix T1
Laser Operational Safety Procedure)

Serial Number: _____

(Assigned by ESH&Q Document Control x7277)

***Attach the Task Hazard Analysis (THA) related to this procedure**

Issue Date:		**Expiration Date:**	
Title:	Laser Safety Procedure for the Polarized 3He Target in Hall C and Laser Room		
Location:	Hall C and the laser room 97a		
Description of Project	Safe operation of the polarized He3 target laser system in Hall C and the laser room 97a		
Document Owner(s):	Jian-ping Chen	**Date:**	10/29/2019

Laser Inventory

	Laser Serial #	Laser Class	Wavelength(s)	Maximum Power/Energy
1.	Raytum 1-10	4	795 nm	30 Watt
2.	First 4: 13-4007, 151029JLAB006, 520698, 1314006			
3.	Others on file			
4.				

Approval Signatures:	**Print**	**Signature**	**Date:**
Laser System Supervisor:	Jian-ping Chen		10/29/2019
Laser Safety Officer:	**Paul Collins**		
Division Safety Officer	**Ed Folts**		
Department or Group Head:	**Cythia Keppel**		
Other Approval(s):			

Document History:

Revision:	Reason for revision or update:	Serial number of superseded document

Distribution: ESH&Q Document Control (x7277, MS6B); affected area(s); Document Owner; Division Safety Officer

A polarized ^{3}He target system was built and used for several JLab experiments. A number of new experiments will continue use the polarized ^{3}He target system in the future. The polarized ^{3}He target is based on the principle of spin exchange between optically pumped vapor of Ru-K mixture and ^{3}He gas. Several high power (30 Watts) 795 nm diode lasers will be used for the optical pumping. A laser room outside the hall is built to house the lasers. This LOSP describes the setup of the laser system in the laser room and at the target area, details the potential hazards associated with the operation of this setup and provides instructions for the safe and effective use of the equipment. In addition, this manual provides information about the functioning of the various safety systems installed to protect personnel and equipment.

Personnel Only those authorized by the LSS are permitted to enter the location noted on the cover sheet of this document.	List: • Training and qualification requirements (including refresher training). • Medical requirements. • Spectator protection requirements.

The 30 watts infrared diode lasers may only be operated by personnel who have:
_ completed a Laser Safety training course (SAF114O) administrated by DOE.
_ completed and passed an ophthalmological exam;
_ had a safety walkthrough by the Laser Safety Supervisor of the Polarized ^{3}He Target System (Jian-ping Chen);
_ read this document;
_ been added to the authorized list of Laser Personnel, included as the last page of this LOSP.
Jefferson Lab personnel or outside visitors, who have not completed all of above training, are only allowed to enter the laser control area under the following conditions:
_ have permission of the Laser Safety Supervisor of the Polarized ^{3}He target system
_ be accompanied by a laser authorized personnel
_ if the laser is operational, with required safety goggles
_ if any equipment, including the laser, is operational, no touching of equipment due to electrical hazards.
_ Briefed by the LSS on the possible hazards associated with the laser system and controls measures in place to provide for their protection.

Laser	Define: • Laser system specifications. • Define laser system components. • Copy of laser operating manuals or reference the location of the manual(s).

The laser light for experiments is provided by multi (up to 10[1]) 30 Watt, 795 nm solid-state diode lasers. The primary lasers used during the experiment are made by Raytum Photonics Inc. The diode lasers consist of a main enclosure which contains the diode, power supplies, fans and control systems for the laser. The laser light from the diode is sent into a long optical fiber which extends out of the main enclosure and goes into Hall C. The fiber is 110 m long in a protective jacket. The lasers operate at diode temperature from 15_C to 26:5_C depending on the system. They are run at output power of up to 30 Watts which uses an operating current of 35-40 Amps. The output laser light has a central wavelength of 795 nm with a spectral width of less than 0.3 nm. The fiber diameter is 600 microns. The beam divergence is < 0:20 N.A.
The lasers have a computer (PC) control system. The control allows adjustments in operating current (and therefore the laser power), diode temperature and the wavelength within a small range.

During the experiment the lasers will be controlled remotely in the Hall C Counting House (after the initial procedure to turn on in the laser room, see below). There is a GUI interface for each of the lasers, which allows

remote control, monitoring of current, temperature and wavelength as well as being able to turn each laser on and off.
The main Laser specifications are outlined in Table 1.1. For more specific information, we refer to the Raytum diode laser users manual which will be available in the lab.

Specifications	Raytum Laser System
Operational Specifications	
Output power	30 W
Mechanical Specifications	
Weight	60 pounds
Cooling Requirements	None required
Delivery Optical Fiber Bundle	0.6 mm diameter
Delivery Fiber Length	5.0 meter nom.
Delivery Fiber Termination	SMA 905 conn.
Operational Specifications	
Typical Operating Temperature	15°C to 35°C
Typical Storage Temperature	−20°C to 65°C
Humidity (non-condensing)	20% to 80%
Electrical Specifications	
Input Power	115 Vac 60 Hz
Optical Specifications	
Beam Characteristic	Semiconductor, multimode
Beam Divergence	< 0.20 N. A.
Diode Laser Center Wavelength	794.7 nm, wavelength tuning 0.8 nm
Wavelength Temp Coefficient	0.27 to 0.30 nm/°C
Emission Bandwidth (FWHM)	± 0.2 nm

Table 1.1 Raytum Laser Specifications

Hazards and Mitigation	Define: • Laser-specific hazards. • Occupational exposure hazards beyond laser light (e.g. fumes, noise, etc.). • Credible non-beam hazards (e.g. environmental hazards). • Describe all required personal protective equipment ES&H Manual Chapter 6410 Appendix T2 Laser Personal Protective Equipment (PPE) (include: clothing requirements (e.g.: no reflective jewelry, etc.). • Control of Hazardous Energy (includes beam and non-beam hazards such as electrical)

The primary beam hazards associated with Class IV lasers consists of eye and skin injuries.
Hazard: Eye injury. The most severe eye injuries are caused by viewing the beam either directly or through specular redirection. At an infra-red wavelength of 795 nm most of the laser light entering the eye is absorbed in the retina. The primary adverse effects from direct or specular viewing are blindness and severe retinal burns. The primary adverse effects from accidental viewing are retinal burns. The retina is most sensitive to radiation of this wavelength, and if the laser energy incident to the eye is too high, it can cause an irreversible retinal burn.
Mitigation strategy: This hazard is mitigated by training, professional conduct, optical beam-line layout, adherence to the *Use and Alignment* procedures listed in this document, and proper selection of laser protective eyewear by affected workers. The selection of laser protective eyewear is determined by the wavelength and power of the laser(s) in use as referenced in the *Required Calculations* section. Non-affected workers are protected by the system enclosure, controlled access to the experimental hall during alignment activities, and room interlock system. *Control of Hazardous Energy*- Lockout/Tagout procedure for fiber bundles to prevent accidental emission transmission.

Hazard: Skin damage Laser radiation of the intensity associated with Class IV diode lasers can also cause irreversible damage to the skin. The damage caused is either associated with temperature rise of the skin tissue following the absorption of laser energy (skin burns) or with surface reactions resulting from photon interactions at the molecular level (photochemical effect), disrupting the normal functionality of the skin tissue.
Mitigation strategy: Establishment of Nominal Hazard Zone (for the 30 Watts diode laser is 78.5 meters for intrabeam and 6.7 meters for fiber-optic output) .

Hazard: Fire – Class 4 lasers are recognized as a potential fire risk.
Mitigation strategy: Remove unneeded combustible material, reduce or properly store flammable material.

Hazard: Some of these lasers described in the LOSP are capable of producing laser generated air contaminants (LGAC).
Mitigation strategy: We do not anticipate use of any materials within the beam enclosure that could produce these contaminants. If we find any LGAC production, laser operation will be shutdown, Industrial Hygiene notified, and material removed and condition resolved before resuming.

Clothing Requirements: Laser workers and spectators must not wear jewelry, watches, portable electronics or clothing that presents a specular reflection hazard.

Laser Environment System designs, including interlocks, require hazard evaluation review by SME.	Define: • Layout of the laser controlled area and/or table. (Show beam location in relation to user (waist height preferable).) • Interlock schematic (or similar) (including smoke detector interlocks). • Room lighting conditions during laser use and alignment procedure(s). • Targets. • Primary and all likely beam paths (open or enclosed).

The laser room layout is shown in Fig. 1.1.
The optical setup is shown in Fig. 1.2, and is made of:
_ Up to ten [2]30 watts, 795 nm solid-state diode lasers (five for each pumping direction) located on two racks in the laser room;
_ Ten[3] long (110 m) optical fibers to transport laser beam from the lasers in the laser room into Hall C;
_ Two 4-to-1 optical fiber combiners, one for each pumping direction;
_ Four lens, two lenses for each laser beam to have it focused at the pumping cell;
_ Two beam splitters to split each laser beam to two beams with linear polarization;
_ Six quarter waveplates, four with rotating motors, to transform each beam from linear polarization to right or left circular polarization;
_ Eight dielectric mirrors to redirect each split beam into the pumping cell;
_ Two transparent windows on the oven to allow the combined laser beams to pass through;
_ One pumping cell to absorb all the laser beam power;
_ One mirror and three optical fibers with lenses for spectral-analyzer and for EPR;
_ One spectral-analyzer for monitoring the pumping cell;
_ One ceramic plate serve as beam dump for each pumping direction.

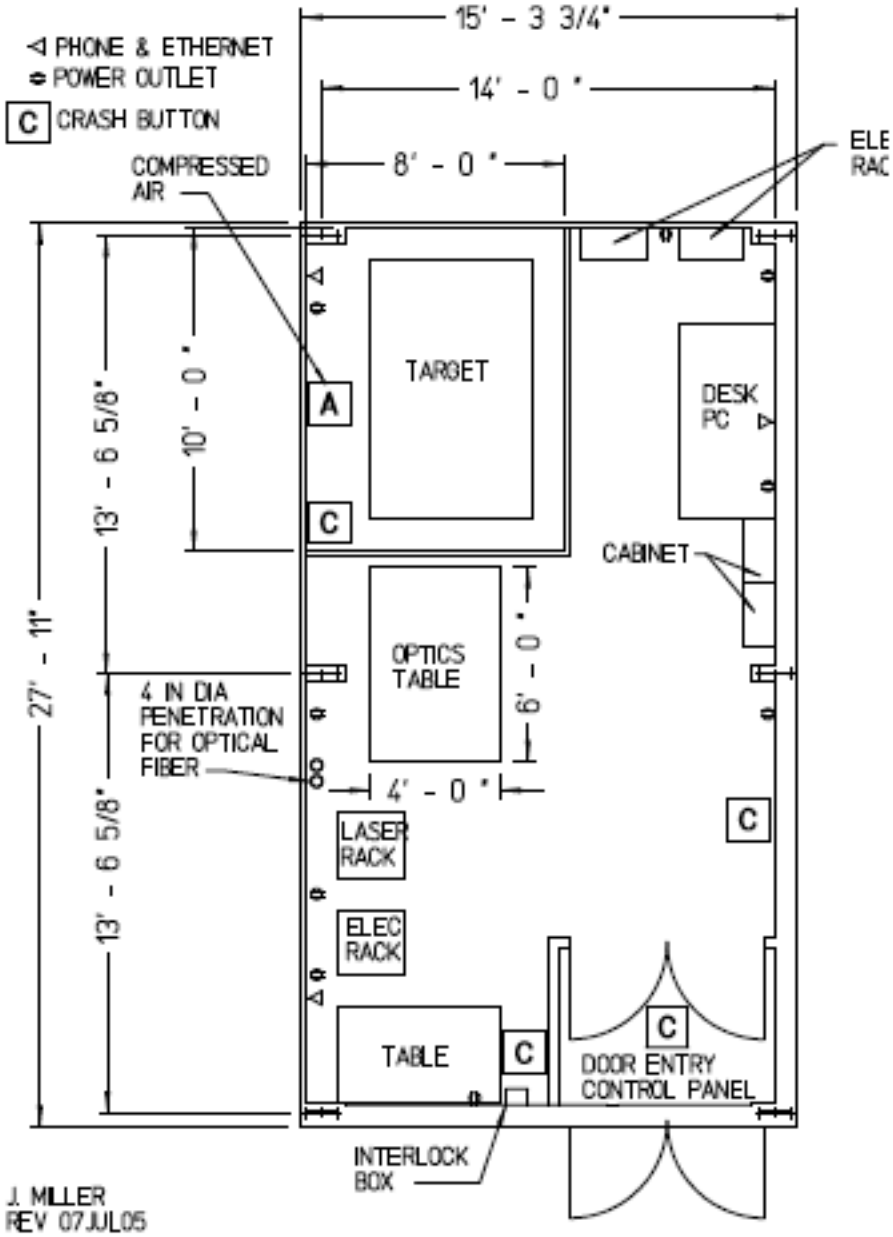

Figure 1.1 Laser Room Layout

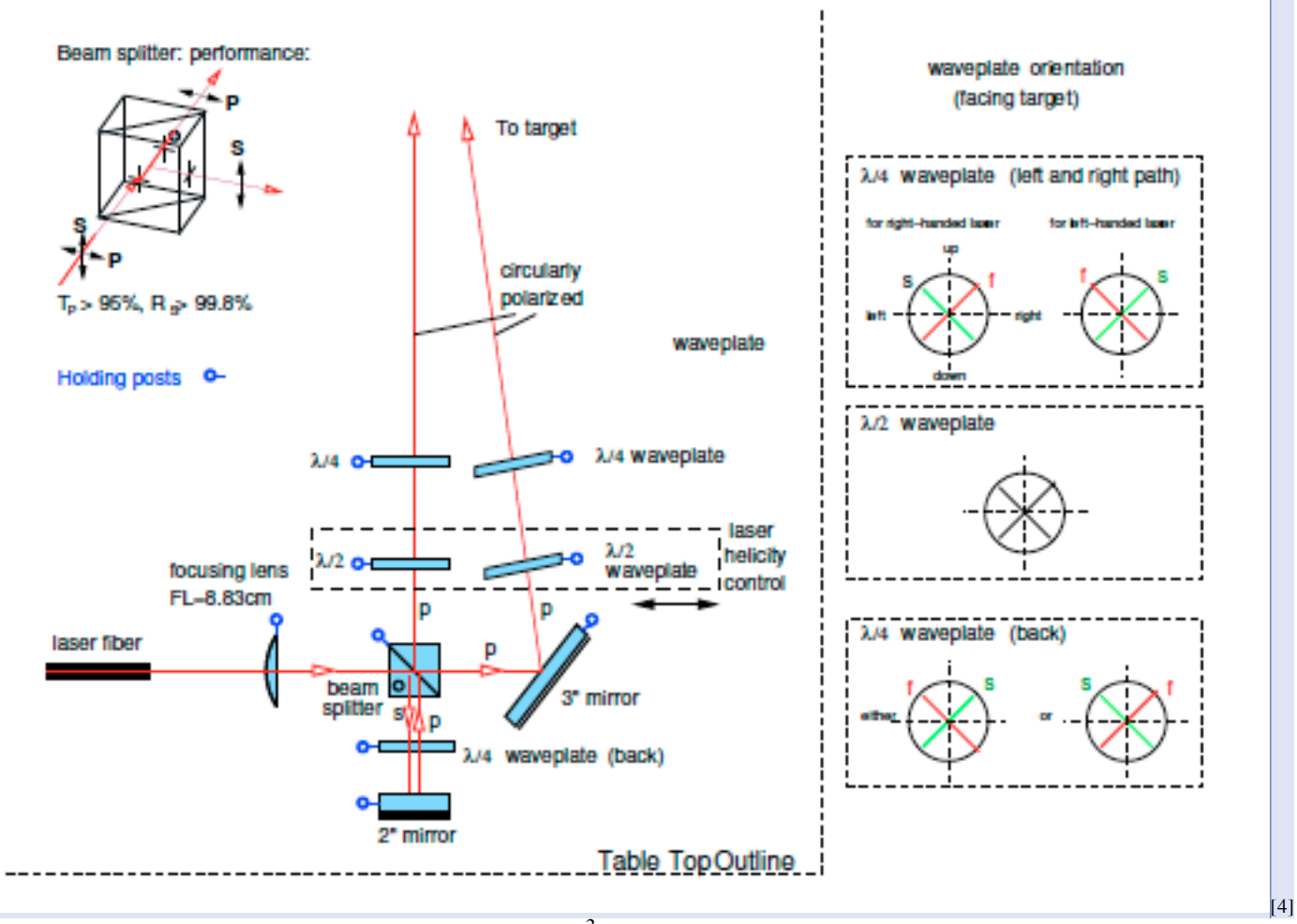

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Figure 1.2 The Polarized ^{3}He Target Laser Optics Setup

For each pumping direction, up to four diode lasers will be used. After passing through the 110-m long fibers, they will be combined to be one beam with a 4-to-1 optical fiber combiner. The combined beam, after passing through two lenses, will be split into two beams. Each one will go through a 1/4 waveplate to transform linear polarization to circularly right or left polarization. All beams, after passing some windows and being redirected by some mirrors, will shoot into a glass pumping cell filled with mixture of Rb-K vapor and ^{3}He gas. The laser beam will be mostly absorbed by the pumping cell. A ceramic plate serves as a beam dump is placed behind the pumping cell. The total path length from the output of the 4-to-1 combiner to the pumping cell is about 5 meters. The pumping cell is inside an oven and connected to a target cell. The whole target assembly is inside two pairs of Helmholtz coils, which provide a magnetic field for the polarization of the target. A NMR system with a pair of RF drive coils and a set of separate pickup coils, A pulse-NMR system and an EPR system are used to measure the polarization of the target.

Written Procedure for Use and Alignment	Provide: • All process steps – including unattended operation controls. • All process steps for detailed alignment – Include manufacturer's protocols for alignment. • Maintenance and service. • Off-normal and emergency procedures (e.g. beam loss, fire).

In this section, we review the various procedures that are required to operate the laser and optical devices. Hazards are least likely to occur during normal operation when laser beams are switched on. During tests, maintenance and/or alignment, beam hazards are more likely.

At all times, when operating the diode lasers in lasing mode while the beam path is not fully enclosed, safety goggles are required.

1. Normal procedure

In the operation mode, each diode laser is in lasing mode rendering an output power of approximately 30 W. The laser beam is already aligned, properly focused and directed into the pumping cell. All the laser beam pipes and the laser enclosure on top of the target are securely installed. The lasers are interlocked with the laser enclosure and the entrance door of the laser room.

Working with the lasers in normal operational mode while the laser path is not fully enclosed will require protective eye wear with a minimum optical density (OD) of 5[5] at wavelength of 795 nm. Before starting the laser in its normal operation mode personnel have to enable the laser safety interlock box. This will cause access to the laser room to be in a controlled mode. Authorized personnel with an access code can bypass the interlock for 45 seconds when entering the laser room. Unauthorized personnel entering the room will cause the lasers switching to stand-by mode when the door is opened. If the laser is to be unattended for a long time, the power should be switched off.

Thus the general procedures for normal operation of the diode lasers in the target laser room are:
_ Enable laser safety interlock box;
_ Wear protective eyewear;
_ Switch on AC power;
_ Turn on the control box with a key;
_ Turn laser to Ready and then On.

After using the above procedures to turn on lasers, when the laser path is fully enclosed and the laser interlock system engaged, lasers can then be turned on and off remotely in the Hall C Counting House through a computer control program with a GUI interface for each laser.

2. Alignment procedure

All the mechanical stands supporting the optical components have been designed and surveyed in order to achieve a preliminary safe alignment of the entire setup (laser off).
Initial alignment will be done with a standard class 3R[6] HeNe laser (class 3R after attenuation, 650 nm) or a laser pointer (class 3R). Laser safety goggles are mandatory for all procedures except for alignment using class 3R HeNe laser or a laser pointer. Use precaution for class 3Rlaser when using the HeNe laser or laser pointer: Do not look directly into the beam or use collecting optics. The final alignment will be done with the diode laser

but at a reduced laser power (less than 10 amps, when the laser spot on a card can be clearly seen with IR viewer). The alignment is performed with one laser beam line at a time. The beam can be tracked by the use of either an IR viewing card or an IR viewer. The photosensitive card can be displaced along the beam, and the IR viewer allows the tracking by the light slightly diffused on the optical components.
During this final alignment, the laser enclosure will be taken off and the laser beam will be directed to the target. The area near the target pivot will be laser area. To simplify situation, the whole hall will be classified as laser area. We will use the CANS system to have controlled access. Before the laser alignment starts, a sweep will be performed to clear the Hall. Then the CANS system will be programmed and turned on to only allow authorized laser trained persons to have access to the hall. The door to the BSY tunnel will be locked. The "laser danger" warning sign will be posted at all the entrances. The doors will be checked by pulling the door handle. In addition, a red flashing light will be put at the BSY side of the door. Most of the final laser alignment will be performed during evening and night time to minimize interference with other work going on in the hall. When the alignment stops, all signs will be take off and the CANS system will be disabled and the door to BSY will be unlocked.

3. Maintenance procedure

Replacement of used or damaged optical components of the setup will be made with the laser off (power switched off and unplugged). The positions and orientations of the new components will be mechanically surveyed and extensively checked before turning to any procedure needing the laser on.
When the target enclosure windows need to be opened (such as to inspect the target or to replace a target cell) and the hall is not in laser controlled access, a lockout/tagout procedure must be followed. The lasers must be turned off. All long fibers will be disconnected from the lasers and the long fiber connection ends will be secured in a lock box. All staff working in the vicinity of the target enclosure must apply personal locks to this box in accordance with JLab lockout/tagout procedures. The vicinity area will be determined from the power measurement and with clear danger sign posted. In case of the failure of any electromechanical or electrical or electronic device, the lasers and the other power supplies will be turned off. The Laser power can simply be unplugged and locked out.

To inspect an optical fiber which is connected to a laser in the laser room, the following procedure must be followed:

- _ turn off laser, switch off laser power; remove the key for power and place In lock box; for the ones do not have a key for power switch, unplug and lockout the power cord at the back of the laser[7] while performing the fiber inspection; disconnect the fiber from the laser; then the fiber can be connected to a fiber inspection scope for inspection.

To inspect an optical fiber in the hall, lockout/tag out procedure to lockout all fiber ends at the laser end must be followed:

- turn off laser, switch off laser power;
- disconnect all long fibers from lasers;
- the long fiber connection ends will be secured in a lock box;
- apply your lock to the box.
- then the fiber can be connected to a fiber inspection scope for inspection.

4. Off-normal and emergency procedure

In case of an emergency, power to the laser shall be shut off. This can be performed in three ways.

- Push the Crash button;
- Turn off the control key on the laser power supply;
- Pull the plug from the power outlet.

In the event of a fire, the users shall leave the laser room and/or the hall and pull the nearest fire alarm.
In case anybody is accidentally exposed to the laser beam (direct or indirect), he or she shall immediately contact the Jefferson Lab medical center (phone: 7539, page: 584-7539). If it is off business hours, please contact local hospital emergency. At the mean time, please inform the laser system supervisor (Jian-ping Chen, phone: 7413, cell:757-218-0722) and the laser safety officer (Paul Collins, phone: 5981).

Laser Controls	• Describe all controls (administrative and engineering). (If a different control is recommended the rationale for not using a typical/recommended control.)

Several controls have been added as preventive measures to the laser room and to the direct laser area. We will enumerate these controls here.
1. The laser control area will have danger signs posted and will have a yellow beacon indicating the presence of Class IV diode lasers. Danger sign will also be posted near the target enclosure area.
2. A controlled access interlock system will limit the entrance to the laser room with a coded number pad. The code is given only to the authorized laser users listed at the end of this LOSP with currently valid training.
3. The laser switches are interlocked to allow an opening of the door to turn off the laser (to stand-by).
4. The main power plug to the laser can be easily pulled. It is plugged into a power strip with an on/off switch which can be easily switched off.
5. Protective safety goggles (minimum OD 5.0 at 795 nm) have to be worn when the laser is operational.
6. All laser beam paths outside the laser room are enclosed with beam pipe or other enclosure (except during laser alignment process).
7. All personnel need to fulfill the training requirements as indicated in Section 1 of this document.
8. The LOSP will be posted on the outside door of the laser room to inform personnel about the hazards associated with the setup and the proper procedures. All controls will be inspected every six months and the inspection will be documented.

Required Calculations	• Maximum permissible exposure. • Optical density. • Nominal hazard zone.

1. Maximum Permissible exposure The Coherent FAP-System emit nominal continuous beams of 30 W at a wavelength of 795nm. With a limiting aperture size of 7mm and exposure time of 10 seconds, the calculated MPE is 1:51mW=cm2.
2. Optical Density The minimum Optical Density is calculated for the beam diameter of 0.6 mm with maximum CW power of 30 watts (the worst case) to be 4.70. OD of 5 safety goggles for the wavelength of 795 nm was selected to be used in the lab. With all 4 lasers, when the beams overlap, the combined beam will have a size larger than 4 times the individual size. The power density will be lower than the maximum power density with one laser.
3. Nominal Hazard Zone
The nominal hazard zone is calculated for 3 conditions:

(a) intrabeam: 78.5 meters
(b) after lens: 5 meters
(c) fiber-optic output: 6.7 meters
The condition of use will always be fiber-optic output with nominal hazard zone of 6.7 meters.
The laser hazard zone is minimized by confining operation to an interlocked laboratory or interlocked enclosure.

Labeling/Posting (See ES&H Manual Chapter 6410 Appendix T5 Laser Labeling/Posting Requirements	• Equipment/area labeling/posting requirements. • Area signs.

Optical Fiber couplers shall be labelled "Hazardous Laser Radiation When Disconnected"
Laser Control Area shall be posted: WARNING Class 4 Laser Controller Area –Avoid eye or skin exposure to direct or scattered radiation. – Do not enter when light is illuminated. – Laser eye protection required: OD ≥ 5@795 nm - - Diode Laser, 795 nm – 30 W maximum power

Authorized/Trained Individuals	
Print Name/Signature	**Date**
Jian-ping Chen	
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1.0 Revision Summary

Revision 1.2 – 09/05/19 – Updated TPOC from B.Manzlak to P.Collins per B.Rainey
Periodic Review – 12/22/15 – No changes per TPOC
Revision 1.1 – 07/01/14 – TechPOC changed from D. Owen to B. Manzlak.
Revision 1.0 – 12/05/10 – Updated to reflect current laboratory operations.

ISSUING AUTHORITY	TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.	
ESH&Q Division	Paul Collins	09/05/19	09/05/21	1.2	