LASER STANDARD OPERATING PROCEDURE (LSOP)

Expiration Date: A-06-009

Division serial number_____
(Assigned by Division Safety Officer when complete)

Issue Date:		
Expiration Date: (no more than 3 years from issue date)		
Title of Project: Electron Gun Test Stand		
Location of Use: ITS South Test Cave	Bldg No. 58	Room No. 127
Description of Project: This LSOP describes the laser system used to drive a high voltage electron gun in the injector test stand south cave		

Laser Inventory

Laser Type	Laser S/N	Laser Class (1-4)	Wavelength (nm)	Average Power
1- Diode	N/A	3b	760-860	0.2W max
2- Nd:YV04	V10-A0436 V10-A0024	4	532	11W
3- Ti:Sapphire	122	4	750-900	3W
4- Nd:YV04 (pump)	0248902	4	532	5W
5- Fiber Laser	S/N PA0605581	4	1071	5W
6- SHG apparatus	N/A	4	532	3W

Approvals	Printed Name & Signature	Date
Laser System Supervisor	Joseph Grames	12-15-06
Department/Group Head	Joseph Grames (deputy)	12-15-06
Laser Safety Officer	Patty Hunt	12-15-06
[redacted] Division Safety Officer (Accelerator) JMG		12-18-06

Document History

Revision #	Reason for revision	Serial number of superseded LSOP

Distribution:
Copies to: affected area, authors, Division Safety Officer, EH&S Reporting Manager
(After expiration, forward original to EH&S Reporting Manager for archiving.)
e-copy to Christina Krause + hard copy of sign page

Injector Test Stand A-06-009-LSOP Checklist
Building 58 Room 127

Date 12/20/06

Laser System Supervisor Joe Grames

Person(s) performing test Joe Grames

Reason for Verification Check
☐ Normal 6-month cyclic check
☑ Work performed on the interlock system
(Provide summary of work performed at bottom of page)
☐ Failure of interlock functionality
(Provide detailed information on failure and corrective action taken at bottom of page)

Interlock Verification: Initial each step confirming successful system response to test.

Step 1: Tests of all Crash Switches. JG

Step 2: Tests of Laser table lid interlocks. JG

Step 3: Smoke detector verification test. JG

Step 4: Door interlock switch time delay verification. JG

Step 5: Door interlock verification simulating magnetic lock failure. JG

Step 6: Verify the following:

- Beacons performed properly for all modes of operation JG
- Audible warnings were provided for transitions between modes of operation JG
- Check integrity of Class 1 enclosure(s) for light leaks JG
- Anti-restart of interlock system is functional (once crashed, interlock does not automatically re-enable) JG
- Laser Eyewear of proper OD for relevant wavelength is available outside the laser area. JG
- Laser Eyewear is clean and ready for use with no burn holes or cracks JG
- Laser Warning signs are correctly posted on all housings and entrances JG

Summary of Verification Check:

This is the initial verification of this LSOP in the ITS South Cave and with the new laser interlock. Everything checks out OK. JG. 12/20/06

LASER STANDARD OPERATING PROCEDURE (LSOP)
Expiration Date: _December 18, 2009_

Division serial number_A-06-009-LSOP_
(Assigned by Division Safety Officer when complete)

Issue Date:	December 18, 2006		
Expiration Date: (no more than 3 years from issue date)		December 18, 2009	
Title of Project: Electron Gun Test Stand			
Location of Use: ITS South Test Cave	Bldg No. 58	Room No. 127	
Description of Project: This LSOP describes the laser system used to drive a high voltage electron gun in the injector test stand south cave			

Laser Inventory

Type	Serial Number	Class	Wavelength (nm)	Average Power (W)
1- Diode	N/A	3b	760-860	0.2
2- Nd:YV04	V10-A0436 V10-A0024	4	532	11
3- Ti:Sapphire	122	4	750-900	3
4- Nd:YV04 (pump)	0248902	4	532	5
5- Fiber Laser	PA0605581	4	1071	5
6- SHG apparatus	N/A	4	532	3

Approvals	**Printed Name & Signature**	**Date**
Laser System Supervisor		
Department/Group Head		
Laser Safety Officer		
Division Safety Officer		

Table of Contents

Section 1 – Introduction to LSOP

This Laser Standard Operating Procedure (LSOP) addresses all aspects of safety and conduct specific to the operation and maintenance of the lasers used in building 58, room 127, commonly referred to as: Injector Test Stand South Cave.

The Laser System Supervisor (LSS) is Joseph Grames.

Email: grames@jlab.org
Extension: 7097

A copy of this LSOP is posted online http://www.jlab.org/accel/inj_group/safety/safety.html and at the Injector Test Stand Control Room Safety Board.

Section 2 – Authorized Personnel

A Laser Worker must have completed SAF154 "Laser Safety Training for ITS South Cave". A list of authorized laser personnel is maintained online within the Jefferson Lab Training Database.

To complete SAF154 means the Laser Worker has:

a) been qualified by Jefferson Laboratory Occupational Health Physician (SAF114E) as detailed in Section 6410 of the EHS&Q manual,
b) taken the Jefferson Lab laser safety course (SAF114O) administered by the Laser Safety Officer,
c) taken Lock, Tag and Try (SAF104),
d) read Section 6410 of the EHS&Q manual,
e) completely reviewed this LSOP, and
f) received walkthrough training with the LSS.

Accidental Eye Exposure: Accidental eye exposure to a laser beam requires ***immediate medical attention*** whether injury is apparent or not. The individual should remain and be transported in the upright position.

Clothing Requirements: Laser workers must not wear jewelry or clothing that presents a specular reflection hazard.

Section 3 – Laser Inventory

Copies of all technical data and laser operating manuals can be found at: Injector Test Stand Control Room bookshelf.

Description: Jlab assembled low power diode laser system

Type of Laser / Class	semiconductor diode laser / Class 3b	
Manufacturer	Various. Typical vendors include SDL, Polaroid, Hitachi, Mitsubishi, Sharp.	
Model Numbers	Different for each vendor. The most frequently used diode laser is SDL-5401	
Serial Numbers	Diode lasers are easily damaged and frequently replaced. Furthermore, vendors do not specify serial numbers on the diode laser housings because the housings are too small. For this reason, serial numbers are not recorded in this LSOP.	
Wavelength range	760 to 860nm	
Power Range	Up to 200 mW, 50 mW typical.	
Mode (i.e., time structure)	DC or pulsing at 499 MHz with 50 psec pulse width.	
Beam Diameter (collimated, typical)	3mm $(1/e^2)$	
Divergence (uncollimated, typical)	175 mrad	
Hazards: list whether skin hazard, eye hazard, and affected part of eye.	Skin? YES	Exceeds skin MPE by: 8x
	Eye? YES	Affected part: Retina

Description: Commercial High power laser

Type of Laser / Class	Frequency-doubled Nd:YVO4 / Class 4	
Manufacturer	Coherent	
Model Numbers	Verdi V-10	
Serial Numbers	V10-A0436 V10-A0024	
Wavelength range	532 nm	
Power Range	Up to 11W. 100mW typical	
Mode (i.e., time structure)	DC	
Beam Diameter (collimated, typical)	2.25 mm $(1/e^2)$	
Divergence (uncollimated, typical)	0.35 mrad +/- 10%	
Hazards: list whether skin hazard, eye hazard, and affected part of eye.	Skin? YES	Exceeds skin MPE by: 37 x
	Eye? YES	Affected Part: Retina

Description: Commercial Ti-Sapphire laser system

Type of Laser / Class	Ti-Sapphire / Class 4	
Manufacturer	TimeBandwidth Inc	
Model Numbers	Tiger	
Serial Numbers	S/N 122	
Wavelength range	750-900 nm	
Power Range	500mW	
Mode (i.e., time structure)	499 MHz, 70ps pulsewidth	
Beam Diameter (collimated, typical)	0.3mm ($1/e^2$)	
Divergence (uncollimated, typical)	0.32 mrad +/- 10%	
Hazards: list whether skin hazard, eye hazard, and affected part of eye.	Skin? YES	Exceeds Skin MPE by: 21 x
	Eye? YES	Affected Part: Retina

Description: Commercial Ti-Sapphire laser system

Type of Laser / Class	Frequency-doubled Nd:YV04 for pumping Ti-Sapphire listed above. / Class 4	
Manufacturer	Jenoptik. This laser is contained within the Ti-Sapphire laser housing. Green light does not leave the Ti-Sapphire laser housing. Green light hazard only when the laser cover is removed.	
Model Numbers	JOL-D2.10	
Serial Numbers	0248902	
Wavelength range	532 nm	
Power Range	5 W	
Mode (i.e., time structure)	DC	
Beam Diameter (collimated, typical)	5mm ($1/e^2$)	
Divergence (uncollimated, typical)	0.35 mrad +/- 10%	
Hazards: list whether skin hazard, eye hazard, and affected part of eye.	Skin? YES	Exceeds Skin MPE by: 17 x
	Eye? YES	Affected Part: Retina

Description: Commercial Fiber Laser

Type of Laser / Class	Fiber Laser Amplifier / Class 4	
Manufacturer	IPG photonics	
Model Numbers	YAR-5K-1064-L	
Serial Numbers	S/N PA0605581	
Wavelength range	1071 nm	
Power Range	5W max	
Mode (i.e., time structure)	DC or 499 MHz, 50ps pulsewidth	
Beam Diameter (collimated, typical)	1.7mm ($1/e^2$)	
Divergence (uncollimated, typical)	0.8 mrad +/- 10%	
Hazards: list whether skin hazard, eye hazard, and affected part of eye.	Skin? YES	Exceeds skin MPE by: factor of 52
	Eye? YES	Affected part: retina

Description: Second Harmonic Generator Assembly

Type of Laser / Class	Not Actually a laser. Frequency converter for Fiber Laser Amplifier / Class 4.	
Manufacturer	Jlab design	
Model Numbers	N/A	
Serial Numbers	N/A	
Wavelength range	1071 nm input 535 nm output	
Power Range	3 W max output.	
Mode (i.e., time structure)	DC or 499 MHz, 50ps pulsewidth	
Beam Diameter (collimated, typical)	1.7mm ($1/e^2$)	
Divergence (uncollimated, typical)	0.8 mrad +/- 10%	
Hazards: list whether skin hazard, eye hazard, and affected part of eye.	Skin? YES	Exceeds skin MPE by: factor of 10
	Eye? YES	Affected part: Retina

Section 4 – Hazards & Hazard Mitigation

Laser Specific Hazards

The laser descriptions of section 3 list the eye and/or skin hazards associated with each specific laser under this LSOP. Exposure to the incident beam or specular reflections must be minimized using the mitigations listed below. Refer to the Eyewear Chart of appendix C for specific ND requirements.

- The diode laser systems require eyewear for the listed wavelength.
- The Ti-Sapphire laser listed above has an interlocked housing that prevents exposure to the 532nm Nd:YV04 pump laser. If the housing is in place, Eyewear for 760-900nm is required. If the housing is removed, Eyewear for exposure to the IR beam and the 532nm pump beam is required.
- The Fiber laser amplifier is fiber coupled class 1. The only possibility of exposure occurs at the launch within the Second Harmonic Generator.
- The Fiber Laser Second Harmonic Generator normally operates under a housing that prevents exposure to the 1071nm beam. If the housing is installed, 532nm eyewear is required. If the housing is removed, eyewear must protect against 1071nm and 532nm.

Engineering Controls to Mitigate Laser Exposure

The lab uses an interlocked laser safety system. System is described in detailed in section 7, but its primary purpose is to:

- Include hazard mitigation for laser workers via laser “crash” buttons.
- Provides access control to limit entry to laser area by untrained workers.

Administrative Controls to Mitigate Laser Exposure

- Eyewear: Refer to section 8 for skin and eye MPE calculation results
- Alignment Procedure section 6- Alignment Guidelines. .

Section 5 – Laser Environment

- The laser beam(s) travel in a beam path indicated on the drawing attached in section 9. This drawing shows laser beam location in relation to workers and a typical table layout. The laser system supervisor will maintain and propagate the most recent layout to laser workers as changes are made to the table or laser area.

- Because more than one laser may be on at a given time laser worker(s) must coordinate activity when the laser area is open for alignment.

- The laser terminates either at a beam stop, a diagnostic (e.g., power meter, laser beam analyzer) or a photocathode.

- The lasers described within this LSOP are generally under both local and remote control at all times. Laser workers should be aware that they may start or stop or change intensity without warning.

In addition to laser hazards, the following non-laser hazards exist:

High Voltage and Prompt Radiation: High voltage and prompt radiation hazards exist when high voltage is applied to vacuum components in the ITS South Cave.
Mitigation: The personnel safety system is described in a separate Standard Operating Procedure, see http://www.jlab.org/accel/inj_group/safety/safety.html

High Voltage and Prompt Radiation: High voltage and prompt radiation hazards exist high voltage is applied to vacuum components in the ITS North Cave.
Mitigation: The personnel safety system is described in a separate Standard Operating Procedure see http://www.jlab.org/accel/inj_group/safety/safety.html. Dosimetry is required to access the ITS South Cave when the ITS North Cave is in Beam Permit.

Section 6 – Written Procedures

The laser(s) normally operate as an enclosed Class 1 laser system under remote control. The system layout is shown in section 9. Laser eyewear is not required in this mode of operation. When alignment is performed all personnel in the area must be trained laser workers and wear appropriate protective personnel equipment. Laser eyewear requirements are listed in Appendix C. The laser interlock system will provide appropriate warning indication for the alignment mode as described in section 7.

Maintenance & Service

Maintenance of the laser systems consists of realignment and cleaning. These procedures are described in the vendor manuals and are implemented by laser workers trained on a specific system.

Service (e.g., alignment or replacement of parts) by an outside vendor representative will require a JLAB escort qualified on this LSOP. Vendor representative must provide proof of eye exam and laser safety program.

Photogun access violates the Class 1 laser enclosure. To gain access to the photogun and maintain Class 1 status the photogun vacuum valve must be secured by Lock, Tag & Try as described in Appendix A.

Beam pipe access violates the Class 1 laser enclosure. To gain access to the beam pipe the laser must be appropriately secured by Lock, Tag & Try as described in Appendix A.

Alignment Procedures

Administrative and Engineered Considerations

1. Watches, rings, dangling badges, necklaces, reflective jewelry are taken off before any alignment activities begin. Use of non-reflective tools should be considered.
2. Access to the room is limited to authorized personnel only.
3. Consider having someone present to help with the alignment.
4. All equipment and materials needed are present prior to beginning the alignment
5. All unnecessary equipment, tools, combustible material (if fire is a possibility) are removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the LSS
7. A NOTICE sign is posted at entrances when temporary laser control areas or unusual conditions warrant additional hazard information be available to personnel entering the area.

Alignment Methods to be used for this laser system:

1. There shall be no intentional intrabeam viewing with the eye.
2. Co-axial low power lasers should be used when practical for alignment of the primary beam.

3. Reduce the beam power through the use of ND filters, beam splitters and dumps, or reducing power at the power supply. Avoid the use of high-power during alignment.
4. Laser Protective Eyewear shall be worn at all times during alignment.
5. Beam Control- the beam is enclosed as much as practical, the shutter is closed as much as practical during course adjustments, optics/optics mounts are secured to the table as much as practical, beam stops are secured to the table or optics mounts.
6. Areas where the beam leaves the horizontal plane shall be labeled.
7. Any stray or unused beams are terminated.
8. Invisible beams are viewed with IR/UV cards, business cards or card stock, craft paper, viewers, 3x5 cards, thermal fax paper, Polaroid film or similar technique. Operators are aware that specular reflections off some of these devices are possible, and that they may smoke or burn.
9. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
10. Normal laser hazard controls shall be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.

Off-normal and Emergency Procedures

In Case of Fire, leave the area immediately and pull the nearest fire alarm. A smoke detector within the ITS South Cave will disable the laser power supplies. Notify the LSS after mitigating the emergency.

Section 7 – Laser Controls and Laser Room Interlock

Laser Safety Eyewear	To be worn at all times when Laser Workers perform laser work with open class 3b or greater beam paths or any potential for exposure exists. Refer to Appendix C Eyewear selection chart for OD/ wavelength selection.
Laser Interlock	The laser room interlock controls are shown in section 9 and described in detail online at http://www.jlab.org/accel/inj_group/safety/safety.html
Smoke Detector	Smoke and fire detectors disable Class 4 lasers in the case of smoke or fire.
Laser Beacons	Provide a visual indication of the state of the laser interlock to personnel approaching the laser area. Their operation is described in the interlock section.
Laser Alignment	During alignment the laser interlock is placed in “alignment mode”. This causes the magnetic door locks to activate and the laser beacons to strobe. Access is restricted to trained laser workers (who have an access code).
Laser Start-Stop	The lasers may only be started when the room interlock is set. The lasers are under EPICS control and may start-stop or change power without warning. This is typically not a problem because the lasers are contained in a class 1 enclosure. When the lasers are in alignment mode, the laser worker may override the EPICS control to gain positive local control over the system.
Laser Enclosures	The laser enclosures are light-tight aluminum housings that are interlocked to the room interlock. If the enclosure lid is lifted while the room interlock is in the "Normal" (Class 1) mode, the interlock will crash and the lasers will be secured. The lid may be lifted without crashing the room if the room interlock is placed in alignment mode and all room occupants are wearing goggles.

Section 8 – Required Calculations (MPE / NHZ / OD)

MPE, OPTICAL DENSITY, AND NOMINAL HAZARD ZONE Calculations
Injector Test Stand Laser Room - Room 129 C

Author: P. Hunt

The MPE, nominal hazard zone, and OD requirement for the eyewear are calculated according to the ANSI Standard for the Safe Use of Lasers A136.1 2000, using software package *EasyHaz Professional* supplied by Laser Professionals Inc.

Laser parameters needed to calculate these values for the ITS Laser system:

Class 3b diodes

1. Diode laser at 760 nm and 200 mW average power, beam diameter 3 mm, beam divergence 175 mrad, CW.

Coherent Verdi V10

2. Commercial Laser: Nd:YVO4, 532 nm and 10 W, beam diameter 2.25 mm, divergence of 0.35 mrad

Ti-Sapphire Laser

3 Tiger laser: 750 nm and 500 mW CW, beam diameter 0.3 mm, divergence of 3.2 mrad.

4. Jenoptik part of Tiger Laser: enclosed Nd:YVO4, 532 nm and 5 W, beam diameter 5 mm, divergence of 0.35 mrad.

Fiber Laser

5. fiber laser at 1.071 microns and 5 W, beam diameter 1.7 mm, divergence 0.8 mrad, multimode fiber

6. fiber laser second harmonic generator assembly 535 nm and 3 W, beam diameter 1.7 mm, divergence 0.8 mrad.

Assumptions:

- The laser beam is collimated.
- The laser beam is circular.
- The laser beam diameter is measured reduced peak intensity of $1/e^2$
- CW beams: exposure 10 seconds for IR lasers, 0.25 seconds for visible lasers
- 7mm limiting aperture in visible and near infrared.
- For diodes: information usually given for diodes includes the divergence for the not collimated beam and the diameter of the collimated beam. The information that is required to calculate the nominal hazard zone is related to the worst case, or collimated beam. The equation used to determine the divergence of the collimated beam is: 1.27 * (wavelength in microns)/(beam waist diameter in mm)

Results:

#	**Laser (type)**	**Worst case MPE/eye (mW/cm^2)**	**NHZ (meters)**	**Required OD (eyeware)**	**Skin Hazard**
1	Diode 760-900 nm	1.32	1.12	2.6	Yes
2	Verdi 532 nm	2.55	3000	4.05	Yes
3	Ti: Sapphire 750-900 nm	1.26	100	3.01	Yes
4	Jenoptik Doubled Nd:YVO4 at 532 nm	2.55	2020	3.71	Yes
5	Fiber laser 1071 nm	5.0	630	3.41	Yes
6	Second Harmonic Generator for seed at 535 nm	2.55	690	3.49	Yes

LASER HAZARD ANALYSIS REPORT

Laser Description:

3b diodes at 760 nm

LASER INPUT DATA

Wavelength:	760 nm
Mode of Operation:	Continuous Wave
Average Power	2E-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^{-1}
Beam Measurement Criteria:	$(1/e^2)$
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	3E+00 mm
Major Axis Divergence:	1.75E+02 mrad
Major Axis M-Squared:	542.54
Minor Axis Diameter:	3E+00 mm
Minor Axis Divergence:	1.75E+02 mrad
Minor Axis M-Squared:	542.54
Intrabeam Observer Range:	0 m
Focal Length of Lens:	na mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	na mm
Minor Diameter on Lens:	na mm
Lens Observer Range:	0 m
Fiber Optic Type:	none
MFD / NA:	na
Fiber Optic Observer Range:	1E+00 m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	0 deg
Beam Diameter on Target:	1 mm
Diffuse Observer Range:	0.5 m
Diffuse Exposure Duration:	1E+01 s

LASER SAFETY RESULTS

Intrabeam/Lens/Fiber Exposure

Small Source Ocular MPE:	1.32E-03 W/cm^2
Worst Case Optical Density:	2.6 OD
OD at Intrabeam Obsr. Range:	2.6 OD
OD at Lens Obsr. Range:	0 OD
OD at Fiber Optic Obsr. Range:	0 OD
Skin MPE:	2.64E-01 W/cm^2
Times Skin MPE:	7.9E+00

NOHD/NHZ Values

Intrabeam Eye NOHD:	1.12E+00 m
Small Source Eye Dif Ref NHZ:	6.9E-02 m
Skin Dif Ref NHZ:	4.9E-03 m
Lens-On-Laser Eye NOHD:	na m
Fiber Optic Eye NOHD:	na m

Diffuse Reflection Exposure

Source Type:	Small
Ocular MPE:	1.32E-03 W/Cm^2
Small Source Eye NHZ	6.9E-02 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0 OD
Fraction of Ocular MPE:	1.91E-02
Skin MPE:	2.64E-01 W/cm^2
Times Skin MPE:	9.7E-05

OTHER CALCULATED VALUES

Average Power:	na W
Peak Pulse Power:	na W
Energy per Pulse:	2E+00 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:	3E+00 mm
Minor Diameter at Range:	3E+00 mm
Peak Irradiance in Eye LA:	na W/cm^2
Avg Irradiance in Eye LA:	5.2E-01 W/cm^2
C_A:	1.32E+00
C_B:	na
C_C:	na
C_E:	1E+00
C_P (Small Source RP only):	na

Easy Haz Professional

LASER HAZARD ANALYSIS REPORT

Laser Description:

ITS South Cave Verdi 532 nm pump for ND:YVO4

Manufacturer:	na
Model Number:	Verdi V10
Serial Number:	V10-A0436 V10-A0024
System Classification:	4
Laser Owner:	Joe Grames
Laser Safety Officer:	Patty Hunt
Laser Location:	Test Lab South Cave

LASER INPUT DATA

Wavelength:	532 nm
Mode of Operation:	Continuous Wave
Average Power	1.1E+01 W
Pulse Duration:	na s
Pulse Repetition Rate:	na Hz
Group Duration:	na s
Group Repetition Rate:	na Hz
Exposure Duration:	2.5E-01 s
Successive Day Exposure:	No
Optically Aided Viewing:	No
Atmospheric Attenuation:	0 cm^{-1}
Beam Measurement Criteria:	$(1/e^2)$
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	2.25E+00 mm
Major Axis Divergence:	3.5E-01 mrad
Major Axis M-Squared:	1.16
Minor Axis Diameter:	2.25E+00 mm
Minor Axis Divergence:	3.5E-01 mrad
Minor Axis M-Squared:	1.16
Intrabeam Observer Range:	0 m
Focal Length of Lens:	na mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	na mm
Minor Diameter on Lens:	na mm
Lens Observer Range:	0 m
Fiber Optic Type:	none
MFD / NA:	na
Fiber Optic Observer Range:	1E+00 m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	0 deg
Beam Diameter on Target:	1 mm
Diffuse Observer Range:	0.5 m
Diffuse Exposure Duration:	1E+01 s

LASER SAFETY RESULTS

Intrabeam/Lens/Fiber Exposure

Small Source Ocular MPE:	2.55E-03 W/cm^2
Worst Case Optical Density:	4.05 OD
OD at Intrabeam Obsr. Range:	4.05 OD
OD at Lens Obsr. Range:	0 OD
OD at Fiber Optic Obsr. Range:	0 OD
Skin MPE:	3.11E+00 W/cm^2
Times Skin MPE:	3.7E+01

NOHD/NHZ Values

Intrabeam Eye NOHD:	3E+03 m
Small Source Eye Dif Ref NHZ:	5.9E-01 m
Skin Dif Ref NHZ:	4.2E-02 m
Lens-On-Laser Eye NOHD:	na m
Fiber Optic Eye NOHD:	na m

Diffuse Reflection Exposure

Source Type:	Small
Ocular MPE:	1E-03 W/Cm^2
Small Source Eye NHZ	5.9E-01 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0.15 OD
Fraction of Ocular MPE:	na
Skin MPE:	2E-01 W/cm^2
Times Skin MPE:	7E-03

OTHER CALCULATED VALUES

Average Power:	na W
Peak Pulse Power:	1.1E+01 W
Energy per Pulse:	2.75E+00 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:	2.25E+00 mm
Minor Diameter at Range:	2.25E+00 mm
Peak Irradiance in Eye LA:	2.86E+01 W/cm^2
Avg Irradiance in Eye LA:	2.86E+01 W/cm^2
C_A:	1E+00
C_B:	4.4E+01
C_C:	na
C_E:	1E+00
C_P (Small Source RP only):	na

Notes:

Easy Haz Professional

LASER HAZARD ANALYSIS REPORT

Laser Description:

Ti Sapphire Tiger at 750 nm

Manufacturer:	Time Bandwidth
Model Number:	Tiger
Serial Number:	122
System Classification:	4
Laser Owner:	Joe Grames
Laser Safety Officer:	Patty Hunt
Laser Location:	Test Lab ITS South Cave

LASER INPUT DATA

Wavelength:	750 nm
Mode of Operation:	Continuous Wave
Average Power	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^{-1}
Beam Measurement Criteria:	$(1/e^2)$
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	3E-01 mm
Major Axis Divergence:	3.2E+00 mrad
Major Axis M-Squared:	1
Minor Axis Diameter:	3E-01 mm
Minor Axis Divergence:	3.2E+00 mrad
Minor Axis M-Squared:	1
Intrabeam Observer Range:	0 m
Focal Length of Lens:	na mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	na mm
Minor Diameter on Lens:	na mm
Lens Observer Range:	0 m
Fiber Optic Type:	none
MFD / NA:	na
Fiber Optic Observer Range:	1E+00 m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	0 deg
Beam Diameter on Target:	1 mm
Diffuse Observer Range:	0.5 m
Diffuse Exposure Duration:	1E+01 s

LASER SAFETY RESULTS

Intrabeam/Lens/Fiber Exposure

Small Source Ocular MPE:	1.26E-03 W/cm^2
Worst Case Optical Density:	3.01 OD
OD at Intrabeam Obsr. Range:	3.01 OD
OD at Lens Obsr. Range:	0 OD
OD at Fiber Optic Obsr. Range:	0 OD
Skin MPE:	2.52E-01 W/cm^2
Times Skin MPE:	2.06E+01

NOHD/NHZ Values

Intrabeam Eye NOHD:	1E+02 m
Small Source Eye Dif Ref NHZ:	1.12E-01 m
Skin Dif Ref NHZ:	8E-03 m
Lens-On-Laser Eye NOHD:	na m
Fiber Optic Eye NOHD:	na m

Diffuse Reflection Exposure

Source Type:	Small
Ocular MPE:	1.26E-03 W/Cm^2
Small Source Eye NHZ	1.12E-01 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0 OD
Fraction of Ocular MPE:	5E-02
Skin MPE:	2.52E-01 W/cm^2
Times Skin MPE:	2.53E-04

OTHER CALCULATED VALUES

Average Power:	na W
Peak Pulse Power:	na W
Energy per Pulse:	5E+00 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:	3E-01 mm
Minor Diameter at Range:	3E-01 mm
Peak Irradiance in Eye LA:	na W/cm^2
Avg Irradiance in Eye LA:	1.3E+00 W/cm^2
C_A:	1.26E+00
C_B:	na
C_C:	na
C_E:	1E+00
C_P (Small Source RP only):	na

Notes:

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LASER HAZARD ANALYSIS REPORT

Laser Description:

Jenoptik 532 nm pump for TiSapphire

Manufacturer:	Jenoptik
Model Number:	JOL-D2.10
Serial Number:	0248902
System Classification:	4
Laser Owner:	Joe Grames
Laser Safety Officer:	Patty Hunt
Laser Location:	Test Lab ITS South Cave

LASER INPUT DATA

Wavelength:	532 nm
Mode of Operation:	Continuous Wave
Average Power	5E+00 W
Pulse Duration:	na s
Pulse Repetition Rate:	na Hz
Group Duration:	na s
Group Repetition Rate:	na Hz
Exposure Duration:	2.5E-01 s
Successive Day Exposure:	No
Optically Aided Viewing:	No
Atmospheric Attenuation:	0 cm^{-1}
Beam Measurement Criteria:	$(1/e^2)$
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	5E+00 mm
Major Axis Divergence:	3.5E-01 mrad
Major Axis M-Squared:	2.58
Minor Axis Diameter:	5E+00 mm
Minor Axis Divergence:	3.5E-01 mrad
Minor Axis M-Squared:	2.58
Intrabeam Observer Range:	0 m
Focal Length of Lens:	na mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	na mm
Minor Diameter on Lens:	na mm
Lens Observer Range:	0 m
Fiber Optic Type:	none
MFD / NA:	na
Fiber Optic Observer Range:	1E+00 m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	0 deg
Beam Diameter on Target:	1 mm
Diffuse Observer Range:	0.5 m
Diffuse Exposure Duration:	2.5E-01 s

LASER SAFETY RESULTS

Intrabeam/Lens/Fiber Exposure

Small Source Ocular MPE:	2.55E-03 W/cm^2
Worst Case Optical Density:	3.71 OD
OD at Intrabeam Obsr. Range:	3.7 OD
OD at Lens Obsr. Range:	0 OD
OD at Fiber Optic Obsr. Range:	0 OD
Skin MPE:	3.11E+00 W/cm^2
Times Skin MPE:	1.67E+01

NOHD/NHZ Values

Intrabeam Eye NOHD:	2.02E+03 m
Small Source Eye Dif Ref NHZ:	2.5E-01 m
Skin Dif Ref NHZ:	7.2E-03 m
Lens-On-Laser Eye NOHD:	na m
Fiber Optic Eye NOHD:	na m

Diffuse Reflection Exposure

Source Type:	Small
Ocular MPE:	2.55E-03 W/Cm^2
Small Source Eye NHZ	2.5E-01 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0 OD
Fraction of Ocular MPE:	2.5E-01
Skin MPE:	3.11E+00 W/cm^2
Times Skin MPE:	2.05E-04

OTHER CALCULATED VALUES

Average Power:	na W
Peak Pulse Power:	5E+00 W
Energy per Pulse:	1.25E+00 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:	5E+00 mm
Minor Diameter at Range:	5E+00 mm
Peak Irradiance in Eye LA:	1.27E+01 W/cm^2
Avg Irradiance in Eye LA:	1.27E+01 W/cm^2
C_A:	1E+00
C_B:	4.4E+01
C_C:	na
C_E:	1E+00
C_P (Small Source RP only):	na

Notes:

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LASER HAZARD ANALYSIS REPORT

Laser Description:

1071 seed amplified to 5W

Manufacturer:	IPG Photonics
Model Number:	YAR-5K-164-L
Serial Number:	PA0605581
System Classification:	Class 4
Laser Owner:	Joe Grames
Laser Safety Officer:	Patty Hunt
Laser Location:	ITS Laser Room

LASER INPUT DATA

Wavelength:	1071 nm
Mode of Operation:	Continuous Wave
Average Power	5E+00 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^{-1}
Beam Measurement Criteria:	$(1/e^2)$
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	1.7E+00 mm
Major Axis Divergence:	8E-01 mrad
Major Axis M-Squared:	1
Minor Axis Diameter:	1.7E+00 mm
Minor Axis Divergence:	8E-01 mrad
Minor Axis M-Squared:	1
Intrabeam Observer Range:	0 m
Focal Length of Lens:	na mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	na mm
Minor Diameter on Lens:	na mm
Lens Observer Range:	0 m
Fiber Optic Type:	multimode
Numerical Aperture:	1.4E-01
Fiber Optic Observer Range:	1E+00 m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	0 deg
Beam Diameter on Target:	1 mm
Diffuse Observer Range:	0.5 m
Diffuse Exposure Duration:	1E+01 s

LASER SAFETY RESULTS

Intrabeam/Lens/Fiber Exposure

Small Source Ocular MPE:	5E-03 W/cm^2
Worst Case Optical Density:	3.41 OD
OD at Intrabeam Obsr. Range:	3.41 OD
OD at Lens Obsr. Range:	0 OD
OD at Fiber Optic Obsr. Range:	0.68 OD
Skin MPE:	1E+00 W/cm^2
Times Skin MPE:	5.2E+01

NOHD/NHZ Values

Intrabeam Eye NOHD:	6.3E+02 m
Small Source Eye Dif Ref NHZ:	1.78E-01 m
Skin Dif Ref NHZ:	1.26E-02 m
Lens-On-Laser Eye NOHD:	na m
Fiber Optic Eye NOHD:	2.2E+00 m

Diffuse Reflection Exposure

Source Type:	Small
Ocular MPE:	5E-03 W/Cm^2
Small Source Eye NHZ	1.78E-01 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0 OD
Fraction of Ocular MPE:	1.26E-01
Skin MPE:	1E+00 W/cm^2
Times Skin MPE:	6.4E-04

OTHER CALCULATED VALUES

Average Power:	na W
Peak Pulse Power:	na W
Energy per Pulse:	5E+01 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:	1.7E+00 mm
Minor Diameter at Range:	1.7E+00 mm
Peak Irradiance in Eye LA:	na W/cm^2
Avg Irradiance in Eye LA:	1.3E+01 W/cm^2
C_A:	5E+00
C_B:	na
C_C:	1E+00
C_E:	1E+00
C_P (Small Source RP only):	na

Notes:

LASER HAZARD ANALYSIS REPORT

Laser Description:

535 nm at 3W second harmonic from 1071 nm

Manufacturer:	Jlab SHG apparatus
Model Number:	N/A
Serial Number:	N/A
System Classification:	Class 4
Laser Safety Officer:	Joe Grames
Laser Location:	Injector Test Stand

LASER INPUT DATA

Wavelength:	535 nm
Mode of Operation:	Continuous Wave
Average Power	3E+00 W
Pulse Duration:	na s
Pulse Repetition Rate:	na Hz
Group Duration:	na s
Group Repetition Rate:	na Hz
Exposure Duration:	2.5E-01 s
Successive Day Exposure:	No
Optically Aided Viewing:	No
Atmospheric Attenuation:	0 cm^{-1}
Beam Measurement Criteria:	($1/e^2$)
Beam Spatial Profile:	circular gaussian
Major Axis Diameter:	1.7E+00 mm
Major Axis Divergence:	8E-01 mrad
Major Axis M-Squared:	2
Minor Axis Diameter:	1.7E+00 mm
Minor Axis Divergence:	8E-01 mrad
Minor Axis M-Squared:	2
Intrabeam Observer Range:	0 m
Focal Length of Lens:	na mm
Spatial Profile on Lens:	circular gaussian
Major Diameter on Lens:	na mm
Minor Diameter on Lens:	na mm
Lens Observer Range:	0 m
Fiber Optic Type:	none
MFD / NA:	na
Fiber Optic Observer Range:	1E+00 m
Diffuse Reflectivity:	100 %
Diffuse Viewing Angle:	0 deg
Beam Diameter on Target:	1 mm
Diffuse Observer Range:	0.5 m
Diffuse Exposure Duration:	1E+01 s

LASER SAFETY RESULTS

Intrabeam/Lens/Fiber Exposure

Small Source Ocular MPE:	2.55E-03 W/cm^2
Worst Case Optical Density:	3.49 OD
OD at Intrabeam Obsr. Range:	3.49 OD
OD at Lens Obsr. Range:	0 OD
OD at Fiber Optic Obsr. Range:	0 OD
Skin MPE:	3.11E+00 W/cm^2
Times Skin MPE:	1E+01

NOHD/NHZ Values

Intrabeam Eye NOHD:	6.9E+02 m
Small Source Eye Dif Ref NHZ:	3.09E-01 m
Skin Dif Ref NHZ:	2.19E-02 m
Lens-On-Laser Eye NOHD:	na m
Fiber Optic Eye NOHD:	na m

Diffuse Reflection Exposure

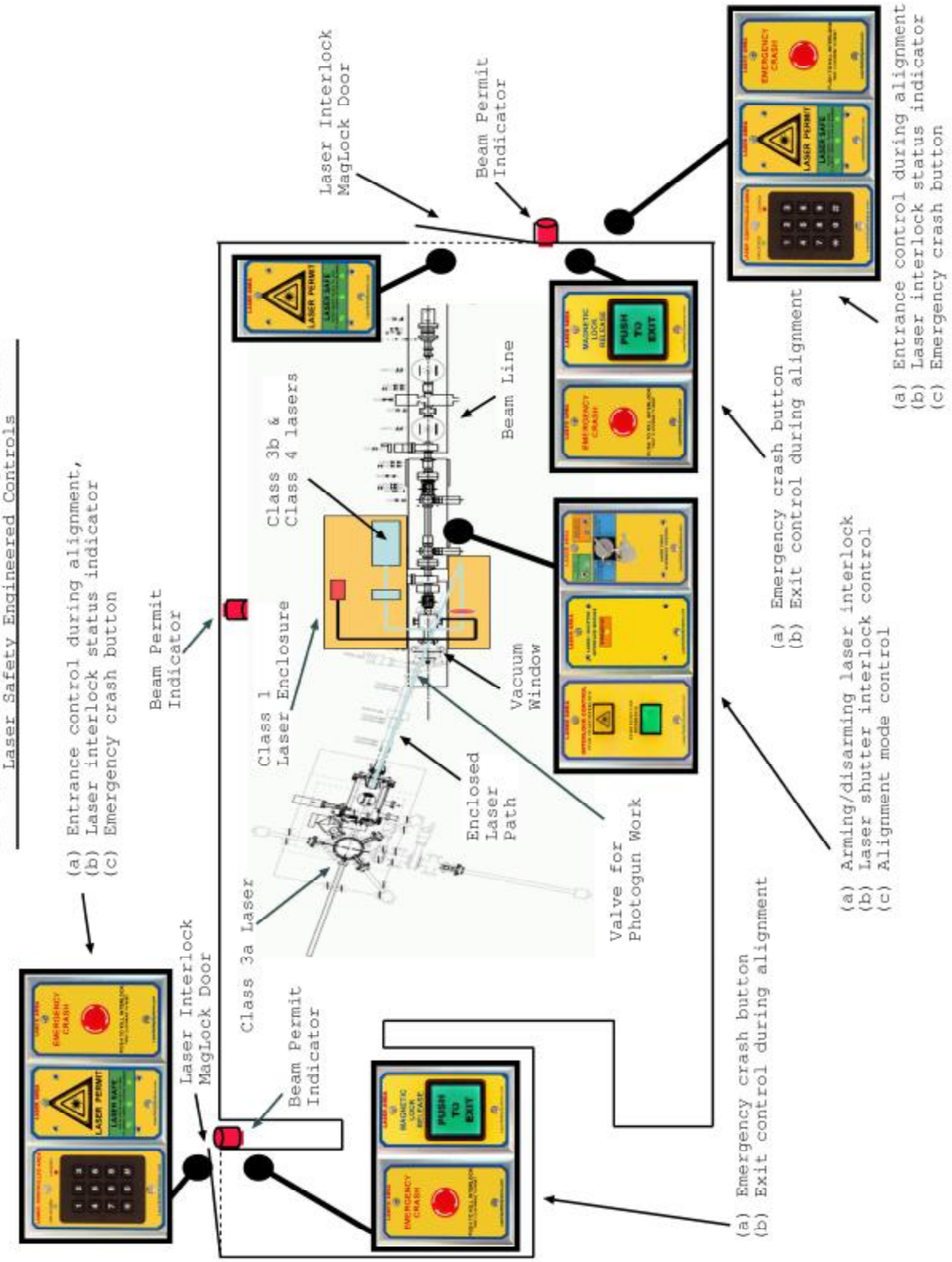
Source Type:	Small
Ocular MPE:	1E-03 W/Cm^2
Small Source Eye NHZ	3.09E-01 m
Extended Source Range:	na m
OD for Diffuse Obsr. Range:	0 OD
Fraction of Ocular MPE:	3.8E-01
Skin MPE:	2E-01 W/cm^2
Times Skin MPE:	1.91E-03

OTHER CALCULATED VALUES

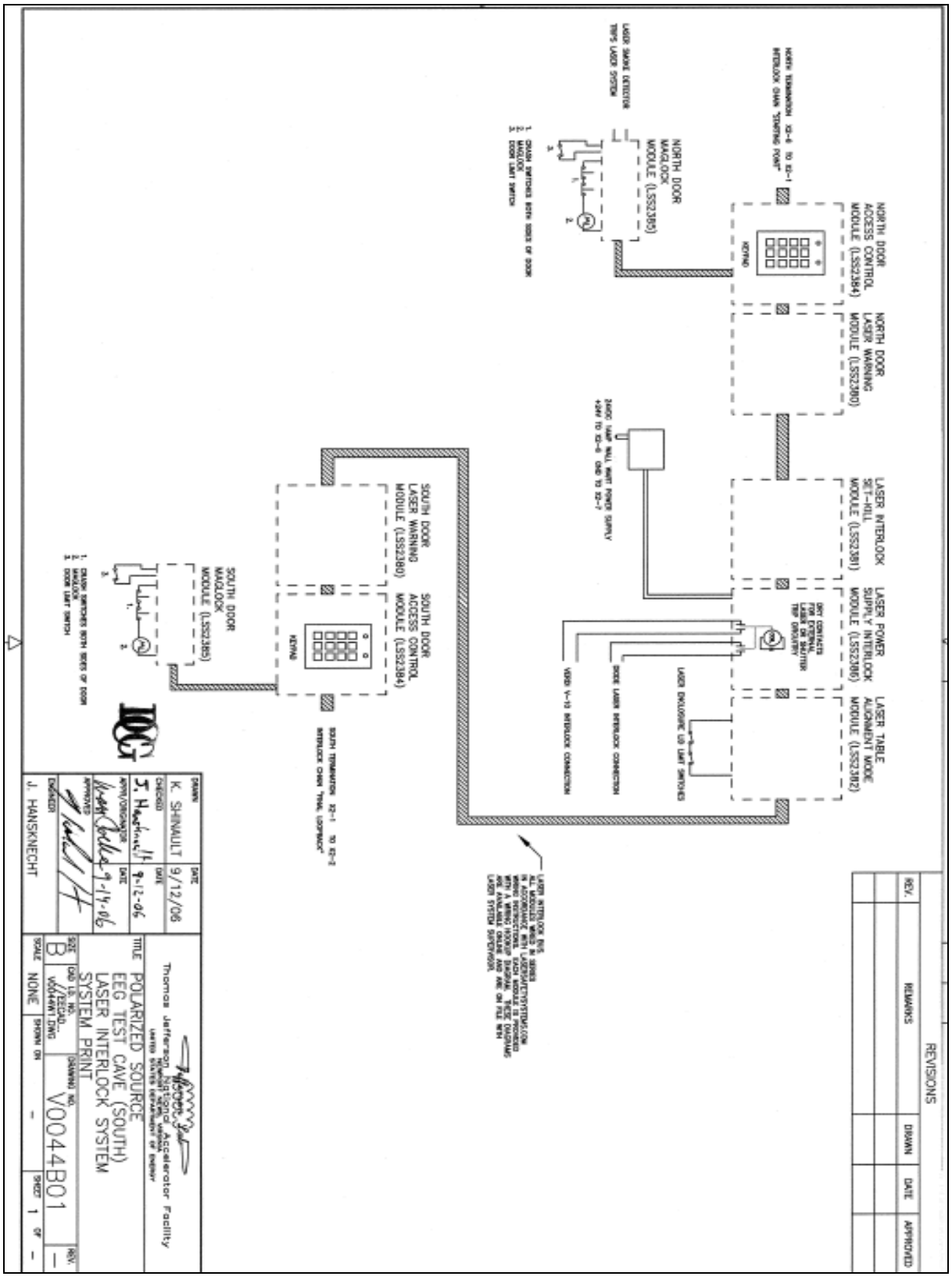
Average Power:	na W
Peak Pulse Power:	3E+00 W
Energy per Pulse:	7.5E-01 J
Duty Cycle:	1E+02 %
Average Power of Group:	na W
Pulses per Group:	na
Groups per Exposure:	na
Pulses per Exposure:	na
Major Diameter at Range:	1.7E+00 mm
Minor Diameter at Range:	1.7E+00 mm
Peak Irradiance in Eye LA:	7.8E+00 W/cm^2
Avg Irradiance in Eye LA:	7.8E+00 W/cm^2
C_A:	1E+00
C_B:	5E+01
C_C:	na
C_E:	1E+00
C_P (Small Source RP only):	na

Notes:

Section 9 – Required Schematics (Laser Area, Table layout, Interlock Schematic)



ITS South Cave Laser System and Engineered Controls



ITS South Cave Interlock Schematic

Section 10 – Labeling examples

Non-interlocked, tooled housings must have indication on label that housing is not interlocked.

All non-interlocked beam pipes must have indication on label that beam pipe is not interlocked.

Entrance to room must have ANSI laser sign that includes entire Class 3b and 4 laser inventory and indication of the nature of laser beams must be noted: invisible and visible.

Entrance to room must have a separate sign if Class 3a lasers are in use. The LSO will provide the sign.

Appendix A – Lock, Tag & Try

The load lock gun high voltage vacuum chamber is routinely accessed to insert new photocathodes. To prevent accidental exposure to laser radiation during this activity **LOCK, TAG & TRY** must first be applied to the electron gun manual gate valve. This manual valve is constructed of stainless steel and fully seals the load lock gun vacuum chambers from the remainder of the vacuum and laser systems.

Procedure for load lock gun vacuum chambers follows:

1. Close the manual gun valve.
2. Apply **TAG** and **LOCK** to handle of manual gate valve.
3. **TRY** to open manual gate valve and if unsuccessful continue, otherwise STOP.
4. Load lock gun is now secured from laser radiation.
5. Perform and complete load lock gun vacuum work.
6. Remove the **LOCK** and **TAG** from the manual gate valve.

The remaining vacuum system (beam line) is rarely accessed. Under special circumstances the laser system will be powered off and **LOCK, TAG & TRY** applied to the power cable.

Appendix B – Interlock Safety Check (Checklist, Frequency, and Procedure)

Interlock functionality verification:

The interlocks system as a whole should be fully tested for functionality:

1. Every six (6) months,

(or)

2. After any modification of the interlock system,

(or)

3. After any failure of the interlock control functionality.

Proof of verification shall be submitted to the LSO after verification. If the event was due to an item 2 or 3 event, laser work shall be terminated until the LSO accepts and approves the verification sheet.

Procedure:

Step 1: Test of the laser interlock crash buttons

a. Arm the system to the normal mode (Class 1 conditions).
b. Depress a single crash switch and do not reset it.
c. Ensure system has dropped to "Crashed" mode as indicated on the warning nodes (Green LED's will be flashing).
d. Ensure the laser interlock relay is not energized. (Laser will not start)
e. Reset the crash button by rotating $1/8^{th}$ turn clockwise.
f. Ensure system returns to "Safe" mode as indicated on the warning nodes (Green LED's will be on solid).
g. Repeat steps 1a through 1f for each crash switch in the system.

Step 2: Test of the Class 1 laser enclosure interlocks

a. Arm the system to the normal mode (Class 1 conditions).
b. Do not energize lasers, (or don protective eyewear).
c. Ensure Alignment mode switch is in normal position.
d. Ensure Green LED on Alignment control node is lit.
e. Lift the lid from the laser table and keep lid open.
f. Ensure system has dropped to "Crashed" mode as indicated on the warning nodes (Green LED's will be flashing).
g. Ensure Green LED on Alignment control node is not lit.
h. Ensure the laser interlock relay is not energized and laser will not start.
i. Return lid to normal position.
j. Ensure system returns to "Safe" mode as indicated on the warning nodes (Green LED's will be on solid).
k. Ensure Green LED on Alignment control node is lit.
l. Repeat Step 2a through 2k for each laser table connected to the interlock system.

Step 3: Test of the smoke detector laser interlock

Note: Specific details for smoke detector verification are posted on the ITS Control Room safety board, however, the main steps are outlined here:

a. Inform proper building authority that smoke detector test will occur.
b. Arm the system to the normal mode (Class 1 conditions).
c. Spray test smoke at laser smoke detector for 5-10 seconds.
d. Ensure system has dropped to "Crashed" mode as indicated on the warning nodes (Green LED's will be flashing).
e. Ensure the laser interlock relay is not energized. (Laser will not start)
f. Reset the smoke detector fault on the main building fire control panel.
g. Ensure system returns to "Safe" mode as indicated on the warning nodes (Green LED's will be on solid).

Step 4: Test of the door interlock switch time delay

a. Arm the system to normal mode, close doors and then raise level to alignment mode.
b. Ensure magnetic locks activate.
c. Push on Door to ensure magnetic locks hold with reasonable force.
d. Test the push-to-exit function and keypad entry function.
e. Once normal functions are verified, use the Push-to-exit button to open the door but hold door open beyond timer limit set on the keypad. (nominally 10 seconds)
f. Ensure system drops to a "Crashed" state after time limit.
g. Return the alignment mode switch to normal mode and ensure system indicates it is back to the normal "Safe" mode as indicated by solid Green LED's on the warning nodes.
h. Repeat steps 4a through 4g on other door.

Step 5: Test of the door interlock simulating magnetic lock failure or forced bypass

a. Arm the system to normal mode.
b. Open the door undergoing test.
c. Ensure opposite door is closed so test will only verify one door at a time.
d. Take alignment mode switch to alignment mode.
e. System will fail at the attempt to lock the door.
f. The system should drop to a "crashed" mode within 4 seconds.
g. Return the alignment mode switch to normal.
h. Ensure the system is normal and ready to arm.
i. Repeat step 5a through 5h on the opposite door.

Injector Test Stand A-06-009-LSOP Checklist

Building 58 Room 127

Date_____

Laser System Supervisor _____

Person(s) performing test _____

Reason for Verification Check

□ Normal 6-month cyclic check

□ Work performed on the interlock system
(Provide summary of work performed at bottom of page)

□ Failure of interlock functionality
(Provide detailed information on failure and corrective action taken at bottom of page)

Interlock Verification: Initial each step confirming successful system response to test.

Step 1: Tests of all Crash Switches. _____

Step 2: Tests of Laser table lid interlocks. _____

Step 3: Smoke detector verification test. _____

Step 4: Door interlock switch time delay verification. _____

Step 5: Door interlock verification simulating magnetic lock failure. _____

Step 6: Verify the following:

- Beacons performed properly for all modes of operation _____
- Audible warnings were provided for transitions between modes of operation _____
- Check integrity of Class 1 enclosure(s) for light leaks _____
- Anti-restart of interlock system is functional (once crashed, interlock does not automatically re-enable) _____
- Laser Eyewear of proper OD for relevant wavelength is available outside the laser area._____
- Laser Eyewear is clean and ready for use with no burn holes or cracks_____
- Laser Warning signs are correctly posted on all housings and entrances_____

Summary of Verification Check:

Appendix C – Laser Goggle Selection Chart

The chart below indicates proper Goggle type and OD requirements based on the laser(s) in operation.

Lasers Specified in this LSOP listed by wavelength output	**Laser eyewear must include a label that specifies a Neutral Density protection greater than:**
532 nm exposure from either: § Verdi V-10 Nd:YV04 § Jenoptiks Nd:YV04 § Second harmonic Generator	**ND > 4.05 at 532 nm**
750-900 nm exposure from either: § Diode laser systems § Ti-Sapphire laser	**ND > 3.01 at 750-900 nm**
1071 nm (1064) exposure from the Fiber Laser Amplifier output	**ND > 3.41 at 1064 nm**

NOTE: If exposure to multiple wavelengths is possible, eyewear must protect against all possible wavelengths.