Laser Standard Operating Procedure (LSOP)
Expiration Date: 11-22-16

Division serial number PHY-13-009-LSOP
(Assigned by Division Safety Officer when complete)

Issue Date:
Expiration Date: No more than three years from the Issue Date

Title of Project: Hall A Compton Polarimeter Laser System

Location of Use: Compton Polarimeter HALL A
Description of Project: Compton Polarimetry of electron beam with laser back-scattering.

Manufacturer	Model	Serial No.	Laser Class	Wavelength (nm)	Power (W)
Innolight	Mephisto	1903	III b	1064	0.2
Innolight	Prometheus	1425	IV	1064/532	2/0.1
JDSU	126-1064-300	121	III b	1064	0.3
JDSU	126-1064-700	279	IV	1064	0.7
HC Photonics	PPLN	AY-Y60405-21-5	IV	532	3
IPG Photonics	YAR-5K-1064-LP-SF	PA0606432	IV	1064	5
IPG Photonics	YAR-10K-1064-LP-SF	PA0706598	IV	1064	10
IPG Photonics	YAR-30K-1064-LP-SF	PA0907863	IV	1064	30

Approvals	Signature	**Date:**
Laser System Supervisor (Sirish Nanda)	Sirish Nanda	11/20/13
Department/Group Head (Cynthia Keppel)	Cynthia Keppel	11/20/13
Laser Safety Officer (Bert Manzlak)	Bert Manzlak, Jr.	11/22/13
Division Safety Officer (Patrizia Rossi)	Patrizia Rossi	11/22/13

Document History:

Revision: **Reason for revision:** **Serial number of superseded LSOP**
PHY-10-003-LSOP

Distribution:
Copies to: affected area, authors, Division Safety Officer, EH&S Reporting Manager
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Hall A Compton Polarimeter Laser Systems

1 Introduction

Many Hall A experiments of Jefferson Laboratory using polarized electrons beams require accurate knowledge of the polarization of the beam. The Hall A Compton Polarimeter utilizing the principle of Compton backscattering of electrons from circularly polarized photons measures the polarization of the electron beam from cross section asymmetry of scattered photons and electrons. Unlike other methods of beam polarimetry that interfere with beam delivery due to placement of a intrusive target in the beam path, Compton Polarimetry is a superior technical solution since it is non-destructive for the electron beam.

A green laser at 532 nm from a frequency doubling crystal, pumped by a fiber amplifier seeded with a 1064 nm infrared laser, is used to generate the circularly polarized photon beam. This 532 nm laser beam is then amplified in a high gain Fabry-Perot cavity, which serves as an intense source of photons for Compton scattering for the CEBAF's polarized electron beam. The scattered electrons and photons are detected using electron and photon detectors. All the devices of the setup are installed on an enclosed optical table, and are controlled and operated in accordance with the requirements of this document. The optical table (1200 x 1800 mm^2) is located in the middle of the Compton Polarimeter magnetic chicane between dipole 2 and 3 as shown in figure 1. The laser systems and optical devices are located in a shielding house, the laser hut, to shield from accidental exposure to hazardous laser light. The laser hut drawing is shown in figure 2.

This Laser Standard Operating Procedure (LSOP) addresses the safe operating procedure for the optical equipment used in the Hall A Compton Polarimeter.

2 Personnel

The laser systems may only be operated by personnel who have

- Completed a Laser Safety course administrated by the laser safety officers at Jefferson Laboratory,
- Read the Laser Safety section of the EH&S Manual (6410),
- Completed and passed an ophthalmologic exam,
- Had a safety walkthrough by the Laser Safety Supervisor and completed training SAF153,
- Read this document,
- Been added to the authorized list of Laser Personnel, included as the last page of this LSOP.

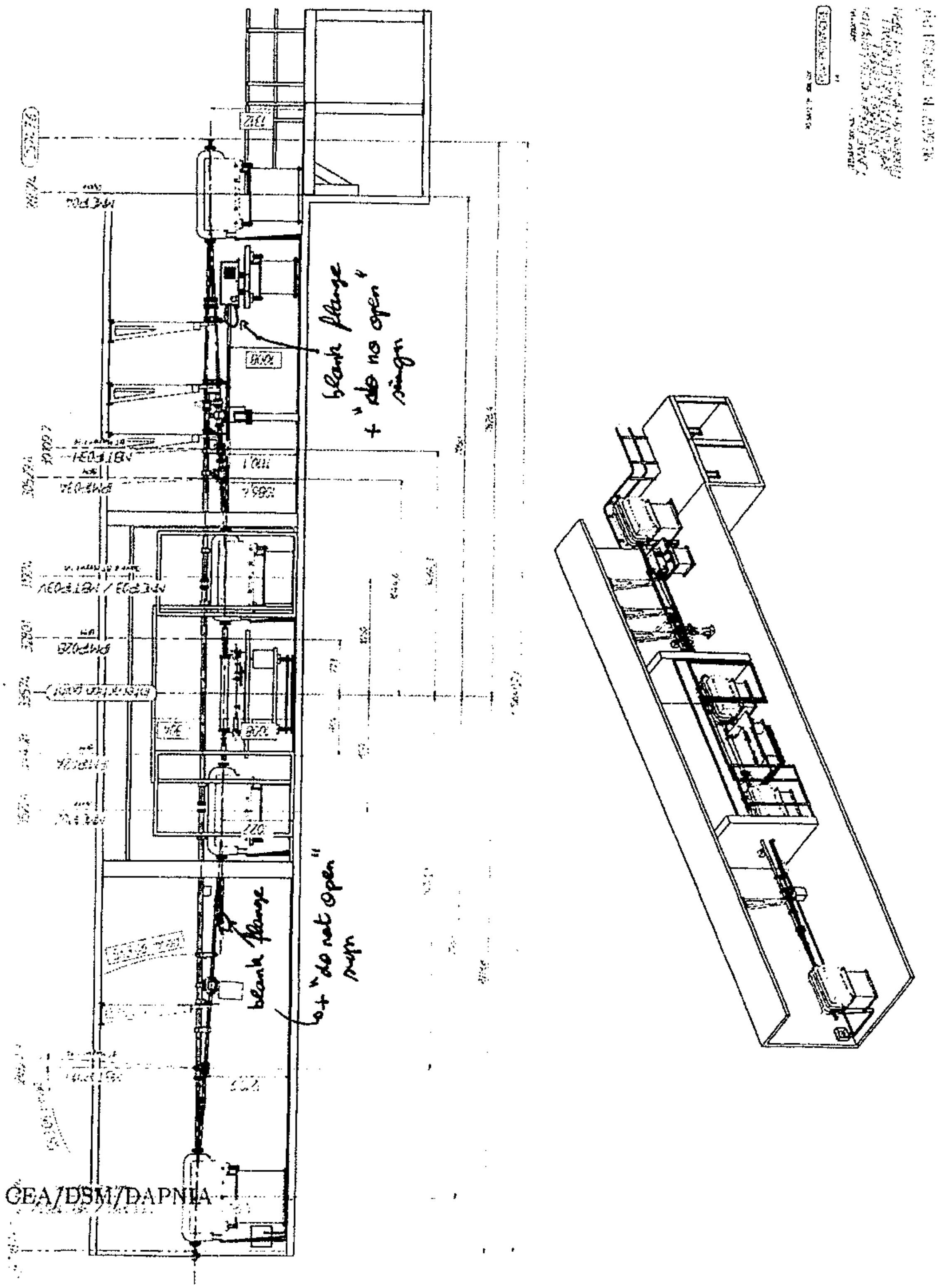


Figure 1. The optical table (1200 x 1800 mm^2) is located in the middle of the magnetic Chicane between dipole 2 and 3.

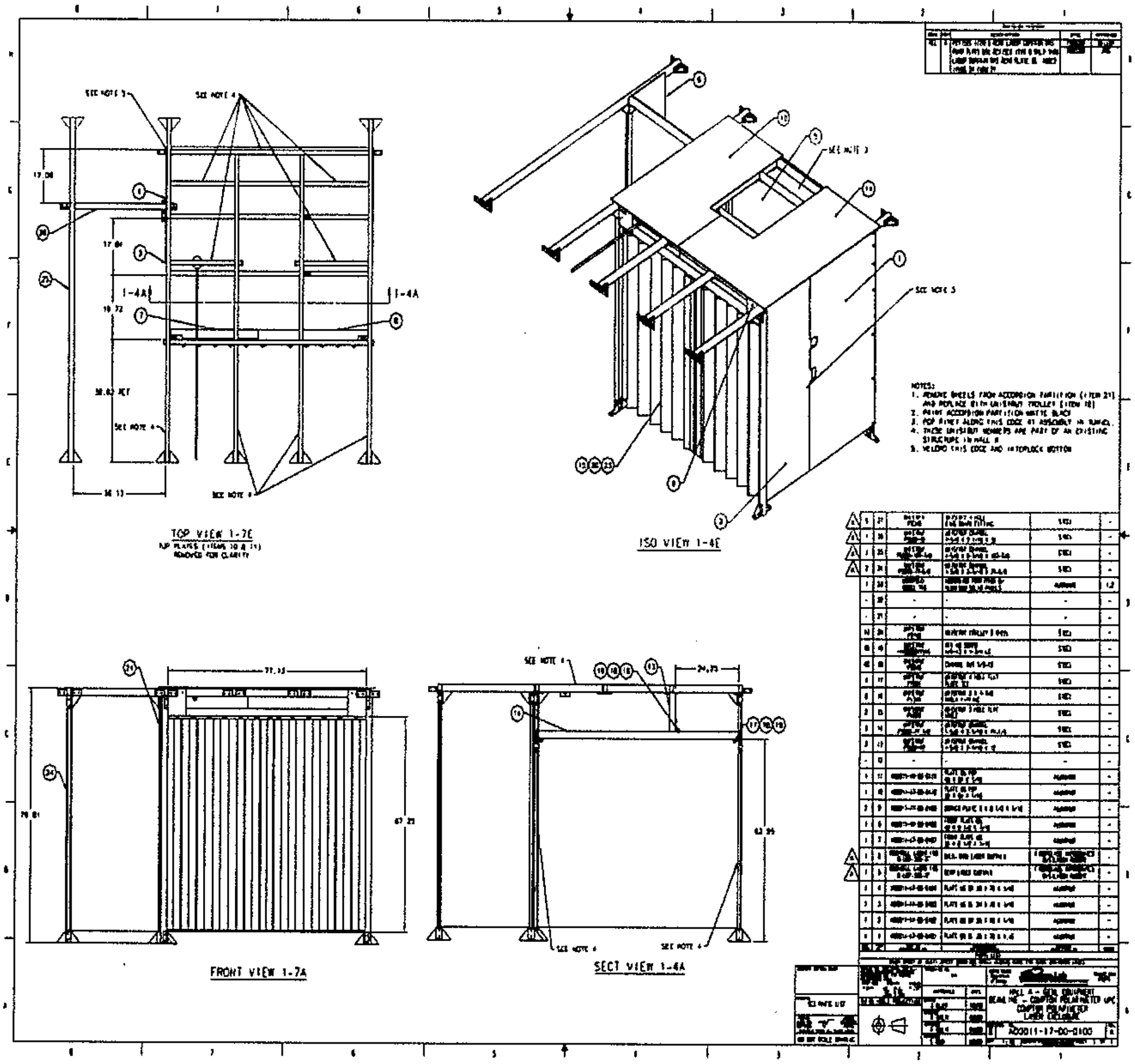


Figure 2. Schematic of the laser hut.

TJNAF personals 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 (Sirish Nanda)
- Be accompanied by a laser authorized personnel
- Laser eye protection is required when the laser system is on. This protection must cover both the infrared (1064 nm) and the green (532 nm) lasers.

3 Lasers

The 532 nm green laser beam used in the CP is generated in a three stage process. A low power fiber-coupled infrared laser at 1064 nm seeds a Ytterbium doped fiber amplifier. The fiber amplifier produces a high power 1064 nm beam which pumps a doubling crystal to produce the 532 nm green beam using second harmonic generation (SHG).

The primary seed laser is the fiber-coupled Mephisto laser , manufactured by Innolight.
The Mephisto is a diode pumped Nd:YAG Non-planar ring oscillator (NPRO) laser. Specifications for the Mephisto laser are shown in Table 1. Backup lasers for the seed are the Innolight Prometheus (Table 2.), the JDSU Model 126-1064-300 (Table 3.), and the JDSU Model 126-1064-700 (Table 4.)

The fiber amplifier is the YAR-10K-1064-LP-SF manufactured by IPG Photonics. It produce up to 10 Watts of 1064 nm CW infrared laser power. The beam is delivered through a fiber collimator. The specifications for the IPG fiber amplifier are given in Table 5.

The doubling crystal is a 50 mm long Periodically Poled Lithium Niobate (PPLN) crystal, supplied by HC Photonics. Pumped with a 1064 nm beam, the PPLN produces the green beam with second harmonic generation (SHG) at 532 nm. When properly tuned, the PPLN setup can produce up to 3 Watts of CW power at 532 nm in a single pass. The specifications of the PPLN green laser is given in Table 6.

Specifications	**Mephisto Infrared laser**
Manufacturer	Innolight
Model	Mephisto S
Serial No.	
CDRH Class	IIIb
Output beam	
Wavelength	1064 *nm*
CW power	200 *mW*
Spatial mode	TEM_{00} ($M^2 < 1.1$)
Spectral linewidth [kHz/100 ms]	1 kHz
Thermal tuning range [GHz]	30
Thermal tuning coefficient [GHz/K]	-3
Thermal response bandwith [Hz]	≅ 1
PZT tuning range [MHz]	±100
PZT tuning coefficient [MHz/V]	≅ 1
PZT response bandwith [kHz]	100
Emission spectrum	Single frequency
Coherence length [km]	>1
Frequency stability [MHz/min]	≅ 10
Relative intensity noise (RIN), f > 10 kHz [dB/Hz]	< -90
RIN with Noise Eater option, f > 10 kHz [dB/Hz]	< -120
Intensity noise, 10 Hz to 2 MHz [% rms]	< 0.5
Waist location (inside laser head) [mm]	95
Size and weight	
Laser head size, w · h · d [mm]	121 · 97 · 175
Laser head weight [kg]	2.5

Table 1: 200 mw Mephisto s Infrared laser specification

Specifications	Prometheus Green Laser
Manufacturer	Innolight
Model	P100
Serial No.	1425
CDRH Class	IIIb
<u>*Output beam*</u>	
Wavelength	532 *nm*
CW power	100 *mW*
Spatial mode	TEM_{00} ($M^2 < 1,1$)
Linewidth, over 1 msc.	1 *kHz**(/ms)***
Thermal tuning range, continuous	10 *GHz*
Thermal tuning coefficient	*-6 GHz*
Thermal tuning rate	10 *GHz/sec*
Piezzo tuning range + 15 V	30 *MHz*
(PZT tuning coefficient (MHz/V))	*(>2)*
(PZT tuning Range(MHz))	*±200*
polarization, linear	> 300 : 1, vertical
Waist diameter, $1/e^2$, vertical	0.35 *mm*
Waist diameter, $1/e^2$, horizontal	0.46 *mm*
Beam divergence, full angle, vertical	3.9 *mRad*
Beam divergence, full angle, horizontal	3.0 *mRad*
<u>*Input and ambient requirements*</u>	
DC voltage/Current max load	+5 V/6 *A*, - 5 *V*/4 *A*
Operating ambient temperature	10 to 45 C°
Relative humidity, non-condensing	10 to 90 %
<u>*Size and weight*</u>	
Laser head, *w, h, d*	14.9,11.1,32.0 *cm*
Mass	3.5 kg
Standard electronics size, *w, h, d*	35, 14, 34 *cm*
Standard electronics weight	10 *kg*
<u>*Power supply*</u>	
Voltage AC	85 *V* to 265 *V*, 50 *Hz* to 400 *Hz*
Electrical power consumption	20 *W* typical, 50 *W* maximum

Table 2: 100 mW Prometheus Green Laser specifications

Specifications	126-1064-300
Output beam	
Wavelength	1064 *nm* (Diode-pumped Nd:YAG)
CWpower	300 *mW*
Spatial mode	TEM_{00}
Longitudinal mode	Single frequency
Amplitude noise *(10 Hz* to *10 MHz)*	< 0.1% rms
Warm-up time	<1 *min*
Linewidth, over 1 msc.	<5 *kHz*
Coherence length, calculated	> 1000 *m*
Frequency Jitter	< 75 *kHz/sec*
Frequency drift, at constant temperature	<50 *MHz/hour*
Thermal tuning range, continuous	10 *GHz*
Thermal tuning range, total	30 *GHz*
Thermal tuning rate	1 *GHz/sec*
Piezzo tuning range + 15 V	30 *MHz*
Piezzo response bandwidth, small signal	> 30 *kHz*
polarization, linear	> 300 : 1, vertical
Waist location from shutter housing	5 *cm* outside laser
Waist diameter, $1/e^2$, vertical	0.43 *mm*
Waist diameter, $1/e^2$, horizontal	0.54 *mm*
Beam divergence, full angle, vertical	3.1 *mRad*
Beam divergence, full angle, horizontal	2.5 *mRad*
Input and ambient requirements	
DC voltage/Current max load	+5 *V*/6 *A*, -5 *V*/4 *A*
Operating ambient temperature	10 to 45 C°
Relative humidity, non-condensing	10 to 90 %
Size and weight	
Laser head, $w \times h \times d$	$7 \times 6 \times 19 cm^3$
Mass	0.9 *kg*
Power supply	
Voltage AC	85 *V* to 265 *V*, 50 *Hz* to 400 *Hz*
Electrical power consumption	20 *W* typical, 50 *W* maximum

Table 3: 300 mW JDSU Infrared Laser specifications.

Specifications	126-1064-700
Output beam	
Wavelength	1064 *nm* (Diode-pumped Nd:YAG)
CW power	700 *mW*
Spatial mode	TEM_{00}
Longitudinal mode	Single frequency
Amplitude noise *(10hz* to *10Mhz)*	< 0.1% rms
Warm-up time	<1 *min*
Line width, over 1 msc.	<5 *kHz*
Coherence length, calculated	> 1000 *m*
Frequency Jitter	< 200 *kHz/sec*
Frequency drift, at constant temperature	< 50 *Mhz/hour*
Thermal tuning range, continuous	10 *GHz*
Thermal tuning range, total	30 *GHz*
Thermal tuning rate	10 *GHz/sec*
Piezo tuning range + 15 V	30 *MHz*
Piezo response bandwidth, small signal	> 30 *kHz*
polarization, linear	> 300 : 1, vertical
Waist location from shutter housing	5 *cm* outside laser
Waist diameter, $1/e^2$, vertical	0.35 *mm*
Waist diameter, $1/c^2$, horizontal	0.46 *mm*
Beam divergence, full angle, vertical	3.9 *mRad*
Beam divergence, full angle, horizontal	3.0 *mRad*
Input and ambient requirements	
DC voltage/Current max load	+5 V/6 *A*, - 5 *V*/4 *A*
Operating ambient temperature	10 to 45 C°
Relative humidity, non-condensing	10 to 90 %
Size and weight	
Laser head, $w \times h \times d$	$7 \times 6 \times 19\ cm^3$
Mass	0.9 *kg*
Power supply	
Voltage AC	85 *V* to 265 *V*, 50 *Hz* to 400 *Hz*
Electrical power consumption	20 *W* typical, 50 *W* maximum

Table 4: 700 mw JDSU Infrared Laser specifications.

Manufacturer	IPG Photonics Corp
Model	YAR-5K-1064-LP-SF Ytterbium Fiber Amplifier
Serial No.	PA0706598
Output Beam	
Wavelength	1064 nm
Maximum Power	5 Watts
Mode	CW, TEM_{00}
Polarization	Linear
Fiber type	Fujikura-980 Panda
Fiber length	2.0 m
Termination	Collimator
Waist diameter ($1/e^2$)	0.9 mm
Input Beam	
Wavelength	1064 nm
Power	2 - 20 mW
Mode	CW, TEM_{00}
Polarization	Linear
Fiber type	Fujikura-980 Panda
Fiber length	1.5 m
Termination	FC/APC-PM Connector
General	
Operating Temp range	0 – 35 ^{0}C
Power Consumption	130-170 Watt
Cooling Method	Forced Air
Dimensions W×H×D	433×133×424 mm 3U 19" rack mount

Table 5. Specifications for the 5W IPG Fiber Laser Amplifier.

Manufacturer	IPG Photonics Corp
Model	YAR-10K-1064-LP-SF Ytterbium Fiber Amplifier
Serial No.	PA0706598
Output Beam	
Wavelength	1064 nm
Maximum Power	10 Watts
Mode	CW, TEM_{00}
Polarization	Linear
Fiber type	Fujikura-980 Panda
Fiber length	2.0 m
Termination	Collimator
Waist diameter ($1/e^2$)	0.9 mm
Input Beam	
Wavelength	1064 nm
Power	2 - 20 mW
Mode	CW, TEM_{00}
Polarization	Linear
Fiber type	Fujikura-980 Panda
Fiber length	1.5 m
Termination	FC/APC-PM Connector
General	
Operating Temp range	0 – 35 ^{0}C
Power Consumption	130-170 Watt
Cooling Method	Forced Air
Dimensions W×H×D	433×133×424 mm 3U 19" rack mount

Table 6. Specifications for the 10W IPG Fiber Laser Amplifier.

Manufacturer	IPG Photonics Corp
Model	YAR-30K-1064-LP-SF Ytterbium Fiber Amplifier
Serial No.	PA0706598
Output Beam	
Wavelength	1064 nm
Maximum Power	10 Watts
Mode	CW, TEM_{00}
Polarization	Linear
Fiber type	Fujikura-980 Panda
Fiber length	2.0 m
Termination	Collimator
Waist diameter ($1/e^2$)	0.9 mm
Input Beam	
Wavelength	1064 nm
Power	2 - 20 mW
Mode	CW, TEM_{00}
Polarization	Linear
Fiber type	Fujikura-980 Panda
Fiber length	1.5 m
Termination	FC/APC-PM Connector
General	
Operating Temp range	0 – 35 ^{0}C
Power Consumption	130-170 Watt
Cooling Method	Forced Air
Dimensions W×H×D	433×133×424 mm 3U 19" rack mount

Table 7. Specifications for the 30W IPG Fiber Laser Amplifier.

Manufacturer	HC Photonics Corp
Model	AY-Y60401-21-5
Crystal Material	5% MgO Doped Lithium Niobate
Dimensions	0.5 × 3 × 50 mm
SHG wavelength	532 nm
SHG Efficiency	2.66 % $W^{-1}cm^{-1}$
SHG power (Maximum)	3 W
SHG beam profile	Same as pump
Operating Temperature	63 ^{o}C

Table 8. Specifications for the PPLN frequency doubled laser.

4 Optical setup

The optical setup is described in figures 3 and 4 and made of three breadboards and the optical cavity on a optical table. The laser beam is provided by three steps: the seeding laser (1064 nm) through fiber laser amplifier to the PPLN doubling crystal for the green laser beam (532 nm). The seed laser and the fiber amplifier along with their controllers are located under the optics table and fiber coupled to the PPLN laser head which sits on the optics table.

On the first breadboard "laser breadboard" (1200 mm × 300 mm) we have:

- The PPLN green laser head
- 1 faraday isolator to protect the laser from optical feedback from further optical elements.
- 1 $\lambda/2$ plate to turn the axis of the linear polarization in order to get it parallel to the table.
- 1 convergent lens to optimize waist at the polarizing stage.
- 1 steering mirror to lead the beam up to the second breadboard.
- 1 polarizing prism (at 90 degrees, there is an integrating sphere with a fast photodetector inside).

On the second breadboard "beam shaping breadboard" (600 mm × 300 mm) we have:

- 1 remote-controlled rotating $\lambda/4$ plate to transform circularly right or left polarization in longitudinal polarization.
- 1 telescope made of 2 lenses (divergent, convergent) to tune waist at the future Compton Interaction Point (CIP).
- 2 two axes remote controlled tuning mirrors; the first one is seen in transmission by a CCD camera.
- 2 mirrors apart from 1152 mm and defining the critical beam line for the polarimeter (the one with the future CIP). Each is seen in transmission by a stopped down 4-quadrants photodiode.

On the third breadboard "diagnostic breadboard" (600 mm × 300 mm) we have:

- 1 harmonic beam splitter to separate the laser beam in order to get two diagnostic beams (these two deviated beams carrying 1% of the initial energy). On one of these beam paths is disposed a CCD camera and on the other is disposed a fast photodetector.
- 1 remote-controlled rotating $\lambda/4$ plate to transform circularly right or left polarization in

longitudinal polarization.

- 1 Calcite Wollaston prism to separate the right and left polarization components.
- 2 Integrating spheres with photodetectors.

The total path length from the laser to the integrating spheres is around 4 m. The "mother" optical table will be at 0.7 m from the floor of the tunnel. There will be three beam heights with respect to the table: 132 mm, 300 mm, and 120 mm. The specifications of the laser system components are summarized in table 7 and 8.

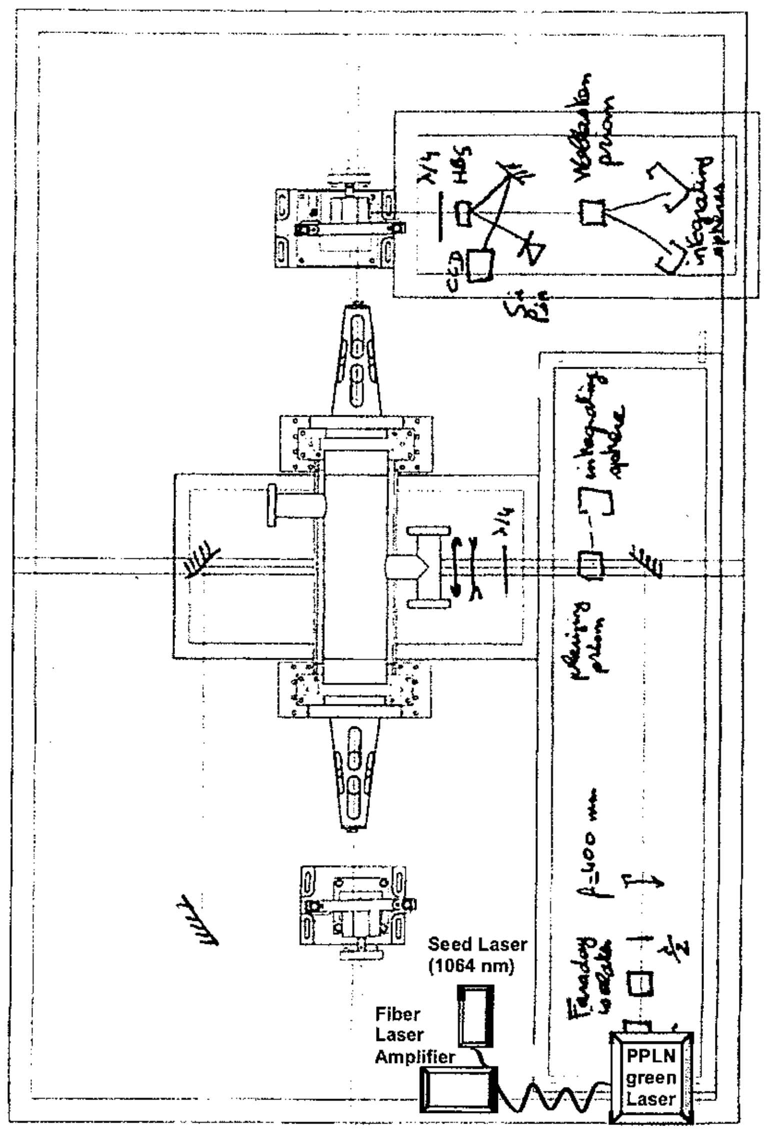


Figure 3: Top view of the Compton Polarimeter optical table.

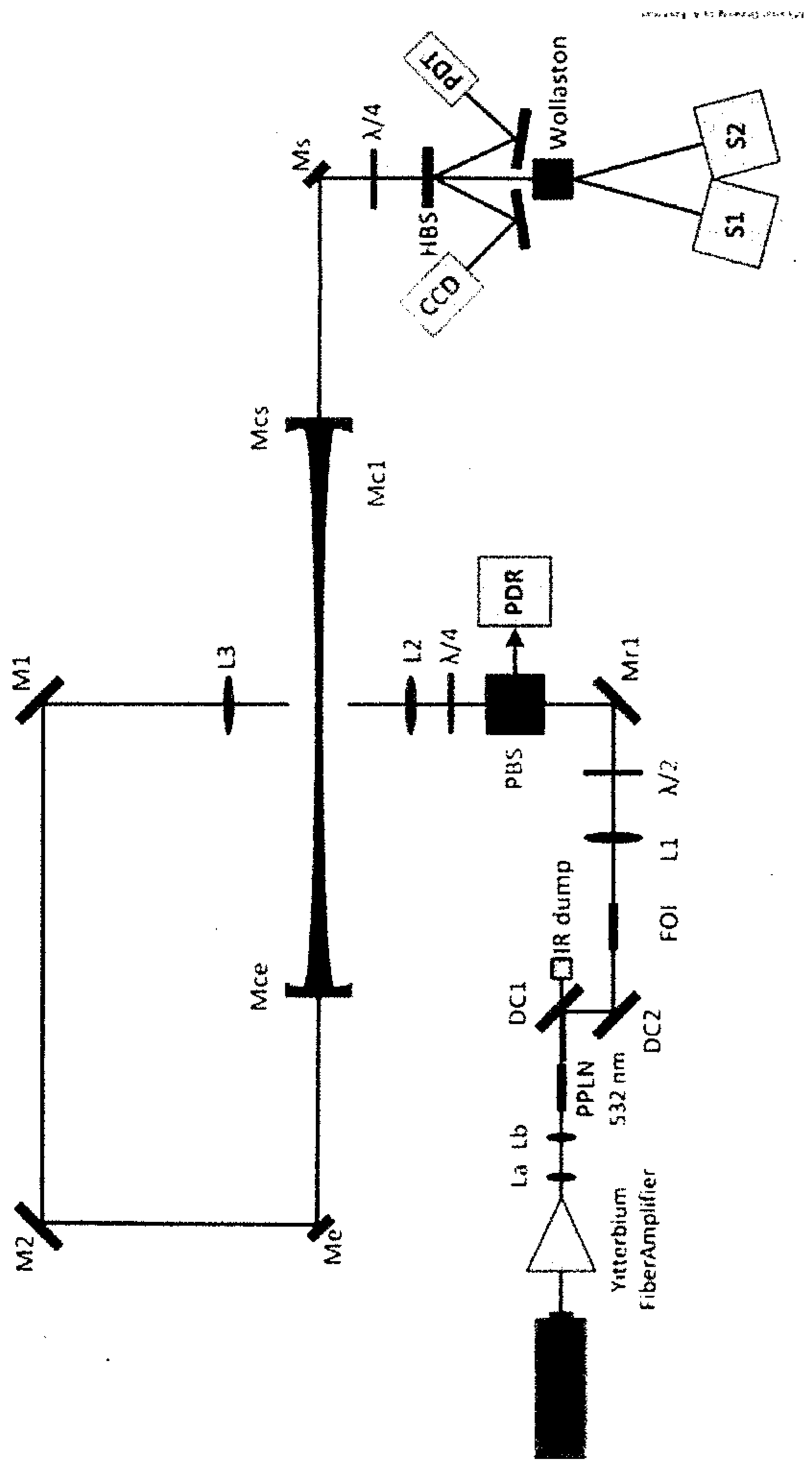


Figure 4: Schematic view of the Compton Polarimeter optical setup. The laser beam starts with a 1064 nm seed laser feeding a fiber amplifier. The amplified beam pumps a PPLN crystal producing the 532 nm green laser beam.

Specifications	
Beam steering motorized plane mirrors	CVI Ref. TLM1-550-45P-1037
Diameter	1.0 in.
Transmittivity	< 0.2 % (measured)
Beam steering motionless plane mirror	Thorlabs Ref. NB1-K13
Diameter	1.0 in.
Transmittivity	< 0 % (measured)
BK-7 lenses AR coated for 532 nm	Thorlabs
focal length	$F1 = -600$ *mm* $F2 = -50$ *mm* $F3 = 175$ *mm*
Diameter	1.0 in.
Faraday isolator	*Unknown*
Isolation	> xxx *dB* (measured)
$\lambda/2$ *plate*	Thorlabs Ref. WPH05M-532
$\lambda/4$ *plate*	Thorlabs Ref. WPQ05M-532
Wollaston Calcite prism	CVI Ref. WLST-20.0-CA-425-675
Extinction ratio	1×10^{-5}
4 cells Si photodiodes	UDT Ref. pin spot4D
Active diameter	6.45 mm^2
Switchable Gain Si Detector	Thorlabs Ref. PDA36A
Active diameter	*13* mm^2
Integrating spheres	Newport Photonics Ref. 819-IS-2
Diffusing material	Spectralon ($R > 99.3$ %)
Inner diameter	50.8 *mm*
Entrance diameter	12.5 *mm*
Holographic Beam Sampler	Gentec-EO Ref. HBS-532-100-1C-10
Polarizing Beam Splitter	Edmund Optics Ref. NT47-630
Extinction ratio	500:1

Table 9: Optical devices specifications.

Specifications	
CMOS CCD	Hitachi Ref. KP-D20B
LCD Monitors	Orion Ref. 8RTF
2 axes remote controlled DC micro-actuators for steering mirrors Traveling range Mechanical resolution *Translation remote controlled DC micro-actuator for the convergent lens* Traveling range Mechanical resolution *Rotation remote controlled step micro-actuator for λ / 4 plate* step resolution	Polytec PI Ref. M-222-50 10 *mm* 0.00014 *degree* Polytec PI Ref. M-226-50 50 *mm* 0.1 μm Suruga Ref. K491-2P 1 *Arcsec.*

Table 10: Electro-mechanical devices specifications

The primary adverse effects from direct or specular viewing are blindness and severe retinal burns. The retina is most sensitive to radiation of this wavelength.

Laser radiation of the intensity associated with Class IV PPLN green laser (532 nm) 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.

Apart from direct beam hazards, two potential non-beam hazards exist in the Laser area described. Firstly, since the PPLN green laser is a Class IV laser, there exists a potential fire hazard. Secondly, there exist electrical hazards due to the high voltage needed to operate the laser, the micro-motors controllers of the remote controlled mirrors and all the measurement devices (110V, 40A). Under no circumstances should the covers of the laser or the different power supplies opened without turning off the main power switches.

6 Laser environments

The PPLN green laser and the associated devices are located in the tunnel, about 7 meters before the entrance of Hall A. The laser controlled area will be delimited by laser attenuator material curtains (a second, external, layer of plastic curtains will protect the enclosed area from excessive dust). The enclosed area will be allowed to have two configurations of the curtains: one up to the opposite wall of the tunnel for the "alignment procedure" and one restricted to the surface of the optical table when in "operational running procedure". In "operational running procedure" a laser safety enclosure will be made of a black aluminum cover box placed on the table and there is an interlock (the laser will be stopped if ever the cover box is removed). The photon beam enters a part of the beam pipe, on each side of this beam pipe, the laser safety enclosure is built by one blank flange. On these flanges, signs will be posted to indicate "DANGER, class IV laser hazard". All of this can be seen on figure 5.

The laser beam path is described as follows (see figure 4):

- Initially the laser beam is horizontal and is pointing left to right in parallel with tunnel (from green wall to Hall A).
- Steered by a mirror, the beam enters the "beam shaping breadboard" with an angle of 90 degrees. It is then pointing towards the wall of the tunnel.
- First optic remote controlled steering mirror rotates the beam over 90 degrees in the horizontal plane. It is then pointing right to left in parallel with tunnel and leave the "beam shaping breadboard".
- The beam is rotated by a motionless mirror over 90 degrees in the vertical plane and is pointing towards the ceiling.
- Then, above, the beam is rotated over 90 degrees by a second remote controlled mirror to get an horizontal laser beam pointing towards the clearance pathway of the tunnel.
- The beam enters the vacuum pipe (when it is in place, i.e. in operational running procedure or for the very last check before covering the setup with the cover box) and is pointing left to right. The beam goes through the cavity.
- 1152 mm farer a new rotation over 90 degrees in the vertical plane makes the beam point to the floor (actually, the optical table). The beam leaves the beam pipe.
- The beam is rotated over 90 degrees in the horizontal plane by the last remote controlled steering mirror and is pointing towards the clearance pathway of the tunnel.
- The beam is finally split by a Calcite prism. The two resulting beams are directed toward two integrating spheres in order to measure the polarization. The spheres then stop the whole beam.

7 Procedures

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 is switched on. During tests, maintenance, upgrades and/or alignment, beam hazards are more likely to occur.

At all times, when operating the lasers in lasing mode, laser safety goggles, that have an optical density (OD) appropriate for that wavelength and energy, are required to be worn. The appropriate OD are is given in Table 11

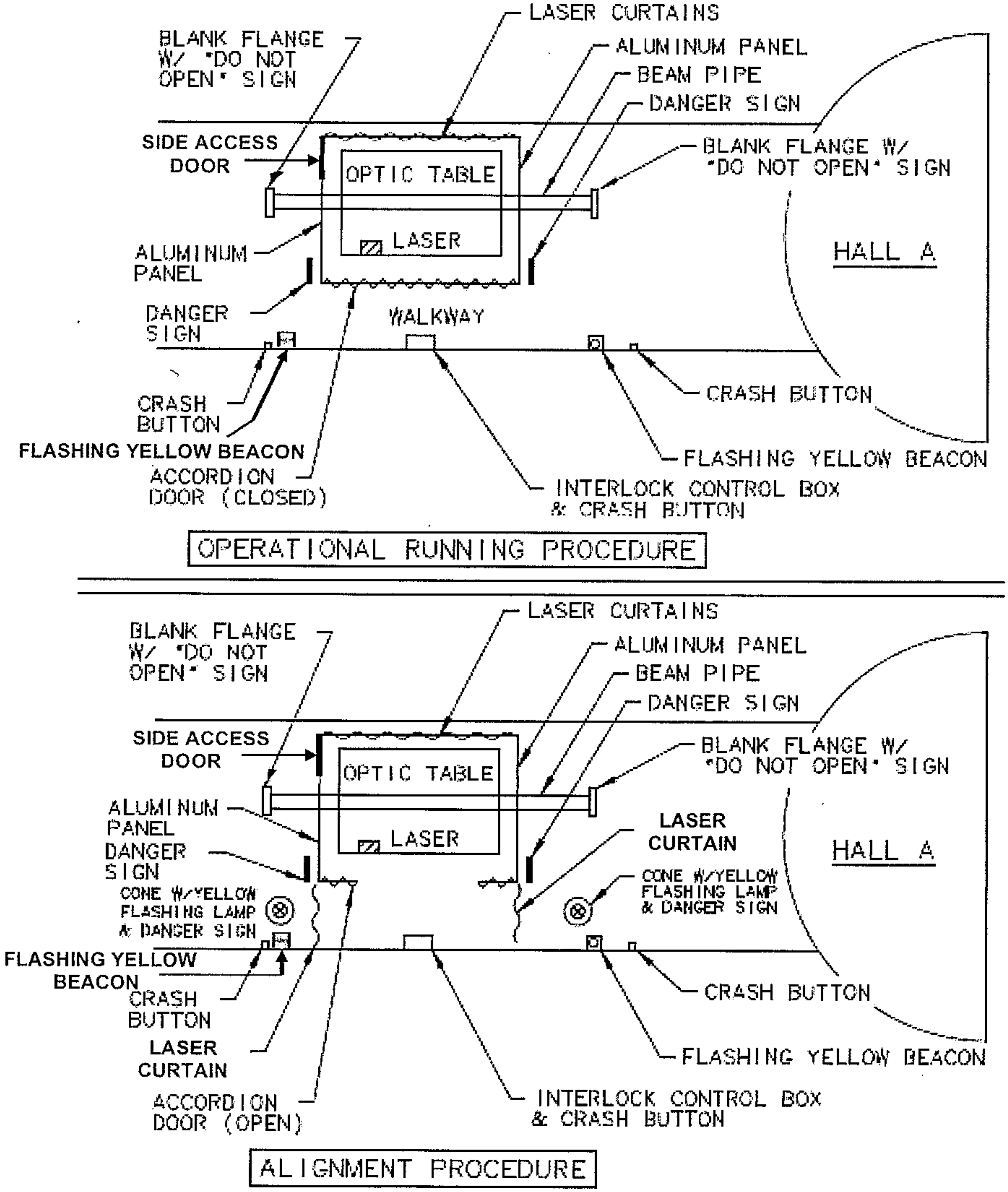


Figure 5: The safety setup for the laser area during operational running and alignment procedures.

7.1 Operational running procedure

The most common normal procedure, when the beam is already aligned and properly focused, is beam polarization measurements and acquisition (performed with the help of a rotating polarizer placed at the entrance of an integrating sphere). The two independent 4-cells photodiodes will see the part of the light transmitted by the two motionless steering mirrors and will be used as the sensor system in a software feedback loop who will automatically adjust the optimal incidence of the beam with respect to the optimal beam line between the 2 little motionless steering mirrors. In this use of the optical setup the safety is insured by:

- laser safety enclosure
  - A black metallic panel is enclose the entire optical setup.
  - The front and the side doors are interlocked with the laser.
  - The blank flanges on each side of the beam line with signs posted to indicate their laser safety enclosure function and that anyone needs the agreement of laser supervisor before removing the flanges.
- A yellow beacon.
- A soft interlock switching the laser off in case the photon beam is lost (no more signal on two position sensitive photodiodes, upstream the optical cavity).

7.2 Alignment procedure

General guidelines for safe alignment procedure of laser setups are given in Appendix A. These general procedures must be adhered to during alignment work of the Compton Polarimeter Optical setup. In addition, the following specific procedure must be followed.

When performing alignment of the optical devices on the table (unlikely to occur often), the access to the tunnel will only be allowed for authorized people working, with laser safety goggles, on the optical setup. The curtains will be extended up to the wall of the tunnel. Outside the laser controlled area delimited by the curtains, the two blank flanges on each side of the beam pipe close the laser safety enclosure. One cone supporting a yellow flashing light will be placed on each side of the enclosure. The upstream and downstream valves on the beam line will be closed (the photon beam won't be able to be reflected far in the main electron beam pipes if it is lost). The EPICS control of these valves will be inhibited on the control panel in Hall A and the connectors on the valves will be disconnected in the tunnel. Then, the cover box will be removed and the interlock will be bypassed. The laser will be operated using the controls of its power supply which is laying under the optical table. 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). Laser on, the beam can be tracked by the use of either a photosensitive screen or a helmet mounted JR viewer. The photosensitive card can be displaced along the beam, and the JR viewer allows the tracking by the light slightly diffused on the optical components. The last fine alignment is electro-mechanically achieved by the two 2 axes mirror micro-actuators under the control of the two position sensitive 4 cells photodiodes. The fine focusing is electro-mechanically achieved by the translation micro-actuators under the control of a beam analyzer. Alignment is attended conditions and may occur during limited access permit. Alignment power for the IPG fiber amplifier is limited to 200mW. Final testing of alignment with no optics manipulation can be at full power for the IPG fiber amplifier.

7.3 Maintenance procedure

Replacement of used or damaged optical components of the setup will be made with the laser off (key turned off and removed). The aperture of the laser will be closed by its shutter. The positions and orientations of the new components will be mechanically surveyed and extensively checked before turning to any procedure needing the laser on.
In case of the failure of any electromechanical or electrical or electronic device, the laser and the other power supplies will be turned off and the out of order devices will be fixed by the sellers service personnel. The Laser is not hardwired, it can simply be unplugged and we don't need any lockout training.

7.4 Off-normal and emergency procedure

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

- Change the position of the control key on the laser power supply.
- Push the crash button.
- Use the control panel of the EPICS slow control in the counting room.

In the event of a fire, the users should push the CRASH button, leave the area, and pull the nearest fire alarm.

8 Controls

Several controls have been added as preventive measures to the Compton polarimeter chicane area and to the direct laser area. The controls will be checked before initial start-up by the LSS and the LSO, and every six months by the LSS. We will enumerate these controls here. A schematic view of the safety interlock controls is shown in Appendix B.

1. The laser control area is posted with danger signs indicating the presence of a Class IV green laser.

2. A yellow beacon will illuminate to indicate operation "Power ON" status. One cone supporting a danger sign and a flashing light will be placed on each side of the laser area when in alignment procedure.

3. The provided two "interlock" pins on the laser power supply will be used to allow an opening of the cover box to turn off the laser when in the operational running procedure (the laser can only be on when the wires connected to the two pins are in contact).

4. A crash button is on the interlock control box situated in the laser safety enclosure when in alignment procedure (welding curtains extended up to the opposite wall and no more pathway in the tunnel).

5. On each side of the laser safety enclosure, upstream and downstream the enclosure, there will be another crash button. So, in case of emergency, somebody (knowing the laser activity by the yellow beacon) can turn off the laser and go through the laser tent.

6. A soft interlock will switch the laser off in case the photon beam is lost when in operational running procedure (no more signal on two position sensitive photodiodes).

7. The main power switch to the laser CIRCUIT box on wall can be easily pulled.

8. Protective safety goggles with OD values as shown in Table 11 have to be worn before turning the laser on when working in the tunnel in the alignment procedure.

9. All personnel need to fulfill the training requirements as indicated in Section 1 of this document.

10. The LSOP will be posted on each side of the laser area to inform personnel about the hazards associated with the setup and the proper procedures.

11. No reflective jewelry is to be worn.

12. Smoke detector interlocked to laser power for class IV laser operations.

9 Laser Safety Calculations

The maximum permissible exposure (MPE), optical density of protective eyewear (OD) and Nominal Ocular Hazard Distance (NHOD) for the lasers are summarized in Table 11. Reference Lazan Laser Hazard Analysis is attached at the end of this document.

Manufacturer	Model	MPE (mW/cm^2)	OD	NOHD (m)	Power (W)
Innolight	Mephisto	2.55	2.009	99.8	0.2
Innolight	Prometheus	5	2.017	101	2/0.1
JDSU	126-1064-300	5	2.193	123	0.3
JDSU	126-1064-700	5	2.561	189	0.7
HC Photonics	PPLN	2.5	3.486	548	3
IPG Photonics	YAR-5K-1064-LP-SF	5	3.415	505	5
IPG Photonics	YAR-10K-1064-LP-SF	5	3.716	714	10
IPG Photonics	YAR-30K-1064-LP-SF	5	4.193	1240	30

Table 11: Laser safety calculations and the appropriate OD for Safety Goggles.

10 List of authorized personnel

The following personnel are authorized to operate the lasers in the optical setup for the Hall A Compton Polarimeter. People can be added to this list by the Laser System Supervisor, Sirish Nanda

By signing below I certify that I have read and understood this document, and that I have completed the training requirements listed in Section 1.

Name	Institution	Signature	Date
Nanda, Sirish	Jefferson Lab (Laser safety Supervisor)		
Camsonne, Alexandre	Jefferson Lab		
Segal, Jack	Jefferson Lab		
Witherspoon, Sue	Jefferson Lab		

APPENDIX A – GENERAL ALIGNMENT GUIDELINES

The techniques for laser alignment listed below will be used to help prevent accidents during alignment of this/these laser system(s).

The requirements for alignment procedures for class 2 and above lasers and laser systems, found in the EH&S chapter "Lasers" and ANSI Z136.1, do not apply to laser pointers, surveying equipment, barcode readers, hand held laser diagnostic equipment or similar general industry equipment.

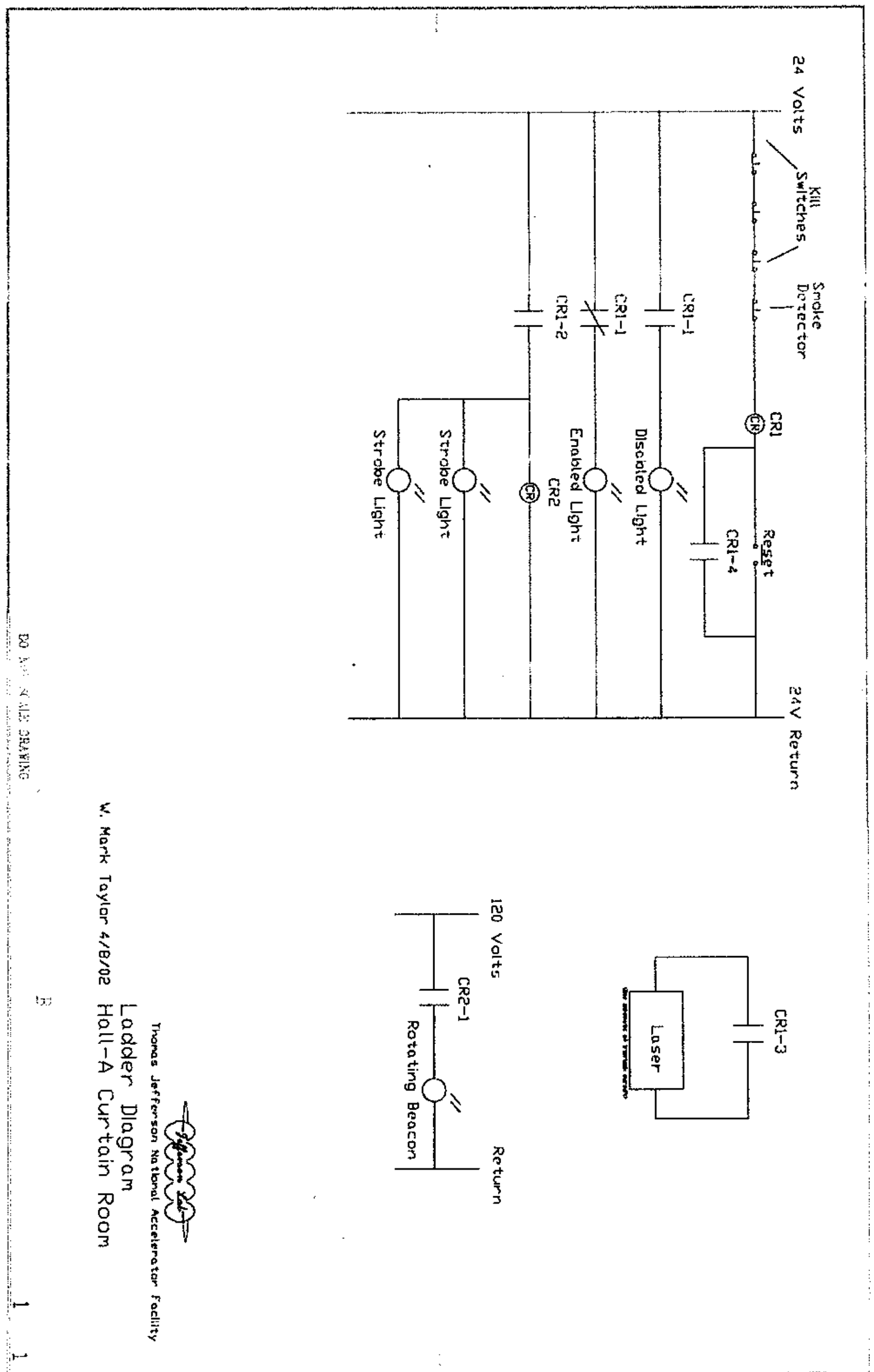
Procedural Considerations:

1. To reduce accidental reflections, 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/area 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) have been removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the RI
7. A NOTICE sign is posted at entrances when temporary laser control areas are setup or unusual conditions warrant additional hazard information be available to personnel wishing to enter the area.

Alignment Methods to be used for this laser:

1. There shall be no intentional intrabeam viewing with the eye. Co-axial low power lasers should be used when practical for alignment of the primary beam.
2. 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 settings during alignment as much as is practical.
3. Laser Protective Eyewear shall be worn at all times during the alignment, within the parameters and notes established on the accompanying laser table.
4. Skin protection should be worn on the face, hands and arms when aligning at UV wavelengths.
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 is possible, and that they may smoke or burn.
9. Pulsed lasers are aligned by firing single pulses when practical.

10. No intra-beam viewing is allowed unless specifically evaluated and approved by the LSO/DLSO. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
11. 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.



24 Volts
Kill Switches
Smoke Detector
CR1
Reset
CR1-4
24V Return
CR1-1
Disabled Light
CR1-1
Enabled Light
CR1-2
CR2
Strobe Light
Strobe Light
CR1-3
Laser
120 Volts
CR2-1
Rotating Beacon
Return
Thomas Jefferson National Accelerator Facility
Ladder Diagram
Hall-A Curtain Room
W. Mark Taylor 4/8/02
DO NOT SCALE DRAWING

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Laser Control Inspection Checklist

(See ES&H Manual Chapter 6410 Appendix T5 Laser Control Inspection Checklist Instructions)

Laser System: Hall A Compton pol. **LOSP Serial Number:**

Control	Sat	Un-Sat
Personal Protective Equipment Laser eyewear/goggles		
Eyewear is available	✓	
Eyewear is clearly marked with the OD and wavelength range protection	✓	*
Check for burn holes or cracks	✓	*
Check integrity	✓	*
Administrative Controls		
Laser hazard warning signs	✓	
Posted and visible on:	✓	
Housing	✓	
All entrances	✓	
Correct sign is used (e.g. caution vs. danger)	✓	
Laser hazard/warning lights are operational	✓	
All users have medical approval	✓	
All users have had safety training	✓	
Access to unauthorized personnel is restricted	✓	
Engineering Controls		
Protective housing intact	✓	

Control	Sat	Un-Sat
Interlocks: (Purposely initiate "Operator Error" to ensure that interlocks are functioning properly.)		
Interlock #1 Description:	✓	
Kill Switch 1		
Interlock #2 Description:	✓	
Kill Switch 2		
Interlock #3 Description:	✓	
Kill Switch 3		
Interlock #4 Description:	✓	
Main Doors		
Interlock #5 Description:	✓	
Side door		
Interlock #6 Description:		
[Start Typing Here]		

Comments::			
Laser System Supervisor	Singh Nanda	**Date**	11/20/13

Distribution: Laser System Supervisor (Original), Laser Safety Officer (Copy)

*Un-satisfactory condition requires removal from service and return to LSO.

Form Revision Summary

Revision 1 – 12/06/10 – Updated to reflect current laboratory operations.

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	EXPIRATION DATE	REV.
ESH&Q Division	Dick Owen	12/06/10	12/06/15	1

This document is controlled as an on line file. It may be printed but the print copy is not a controlled document. It is the user's responsibility to ensure that the document is the same revision as the current on line file. This copy was printed on 11/14/2013.

Industrial LSO

Laser Information

Laser Description/Data:	Mephiistos...
Wavelength Units:	nanometer
Wavelength:	1064.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power: (J) / (W)	Average Power 2.0E-1
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	1.0E+1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	5.00E-03
Skin MPE (W/cm^2):	1.00E+00
Times Skin MPE:	2.08E+00

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or 1/e^2 :	(1/e^2)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	2.017
Worst Case OD:	2.017
Intrabeam NOHD (m):	1.01E+02

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile :	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	3.57E-02
OD at Observer Range:	0.0
Fraction of Ocular MPE:	2.04E-02
Times Skin MPE:	1.02E-04

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	na
Energy (J):	2.00E+00
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	na
(Avg) Eye (W/cm^2):	5.20E-01

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	5.00E+00
Blue light C_B:	na
Pre-retinal C_C:	1.00E+00
Repetitive pulse C_P:	na
T_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	Prometheus...
Wavelength Units:	nanometer
Wavelength:	532.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power:	Average Power
(J) / (W)	1.0E-1
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	2.5E-1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	2.55E-03
Skin MPE (W/cm^2):	3.11E+00
Times Skin MPE:	3.34E-01

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or 1/e^2:	(1/e^2)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	2.009
Worst Case OD:	2.009
Intrabeam NOHD (m):	9.98E+01

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile :	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	3.54E-02
OD at Observer Range:	0.0
Fraction of Ocular MPE:	2.00E-02
Times Skin MPE:	1.64E-05

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	1.00E-01
Energy (J):	2.50E-02
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	2.60E-01
(Avg) Eye (W/cm^2):	2.60E-01

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	1.00E+00
Blue light C_B:	4.37E+01
Pre-retinal C_C:	na
Repetitive pulse C_P:	na
T_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	126-1064-300...
Wavelength Units:	nanometer
Wavelength:	1064.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power: (J) / (W)	Average Power 3.0E-1
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	1.0E+1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	5.00E-03
Skin MPE (W/cm^2):	1.00E+00
Times Skin MPE:	3.12E+00

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or $1/e^2$:	($1/e^2$)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	2.193
Worst Case OD:	2.193
Intrabeam NOHD (m):	1.23E+02

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	4.37E-02
OD at Observer Range:	0.0
Fraction of Ocular MPE:	3.06E-02
Times Skin MPE:	1.53E-04

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	na
Energy (J):	3.00E+00
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	na
(Avg) Eye (W/cm^2):	7.80E-01

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	5.00E+00
Blue light C_B:	na
Pre-retinal C_C:	1.00E+00
Repetitive pulse C_P:	na
T_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	126-1064-700...
Wavelength Units:	nanometer
Wavelength:	1064.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power:	Average Power
(J) / (W)	7.0E-1
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	1.0E+1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	5.00E-03
Skin MPE (W/cm^2):	1.00E+00
Times Skin MPE:	7.28E+00

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or 1/e^2 :	(1/e^2)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	2.561
Worst Case OD:	2.561
Intrabeam NOHD (m):	1.89E+02

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile :	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	6.68E-02
OD at Observer Range:	0.0
Fraction of Ocular MPE:	7.13E-02
Times Skin MPE:	3.57E-04

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	na
Energy (J):	7.00E+00
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	na
(Avg) Eye (W/cm^2):	1.82E+00

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	5.00E+00
Blue light C_B:	na
Pre-retinal C_C:	1.00E+00
Repetitive pulse C_P:	na
T_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	IPG YAR 5K...
Wavelength Units:	nanometer
Wavelength:	1064.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power: (J) / (W)	Average Power 5.0E+0
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	1.0E+1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	5.00E-03
Skin MPE (W/cm^2):	1.00E+00
Times Skin MPE:	5.20E+01

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or 1/e^2:	(1/e^2)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	3.415
Worst Case OD:	3.415
Intrabeam NOHD (m):	5.05E+02

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile :	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	1.78E-01
OD at Observer Range:	0.0
Fraction of Ocular MPE:	5.09E-01
Times Skin MPE:	2.55E-03

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	na
Energy (J):	5.00E+01
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	na
(Avg) Eye (W/cm^2):	1.30E+01

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	5.00E+00
Blue light C_B:	na
Pre-retinal C_C:	1.00E+00
Repetitive pulse C_P:	na
T_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	IPG YAR...
Wavelength Units:	nanometer
Wavelength:	1064.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power: (J) / (W)	Average Power 1.0E+1
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	1.0E+1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm²):	5.00E-03
Skin MPE (W/cm²):	1.00E+00
Times Skin MPE:	1.04E+02

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or 1/e²:	(1/e²)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	3.716
Worst Case OD:	3.716
Intrabeam NOHD (m):	7.14E+02

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	2.52E-01
OD at Observer Range:	0.008
Fraction of Ocular MPE:	na
Times Skin MPE:	5.09E-03

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	na
Energy (J):	1.00E+02
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm²):	na
(Avg) Eye (W/cm²):	2.60E+01

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm²):	na
Rule 2 MPE (J/cm²):	na
Rule 3 MPE (J/cm²):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	5.00E+00
Blue light C_B:	na
Pre-retinal C_C:	1.00E+00
Repetitive pulse C_P:	na
t_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	IPG YAR 30K...
Wavelength Units:	nanometer
Wavelength:	1064.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power: (J) / (W)	Average Power 3.0E+1
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	1.0E+1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	5.00E-03
Skin MPE (W/cm^2):	1.00E+00
Times Skin MPE:	3.12E+02

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or 1/e^2 :	(1/e^2)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	4.193
Worst Case OD:	4.193
Intrabeam NOHD (m):	1.24E+03

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile :	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	4.37E-01
OD at Observer Range:	0.485
Fraction of Ocular MPE:	na
Times Skin MPE:	1.53E-02

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	na
Energy (J):	3.00E+02
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	na
(Avg) Eye (W/cm^2):	7.80E+01

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	5.00E+00
Blue light C_B:	na
Pre-retinal C_C:	1.00E+00
Repetitive pulse C_P:	na
T_1 (s):	na

Industrial LSO

Laser Information

Laser Description/Data:	PPLN@3.0W...
Wavelength Units:	nanometer
Wavelength:	532.0
Mode of Operation:	Continuous Wave

Laser Parameters

Energy / Power: (J) / (W)	Average Power 3.0E+0
Pulse Duration (s):	na
Pulse Rep Rate (Hz):	na
Exposure Duration (s):	2.5E-1

Point Source MPE

(Intrabeam)

Ocular MPE (W/cm^2):	2.55E-03
Skin MPE (W/cm^2):	3.11E+00
Times Skin MPE:	1.00E+01

Intrabeam: Spatial Profile, OD, and NOHD

(OD = Optical Density)

1/e or $1/e^2$:	($1/e^2$)
Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Minor Axis Diameter (mm):	1.0E+0
Divergence (mrad):	1.0E+0
Observer Range (m):	0.0E+0
OD at Observer Range:	3.486
Worst Case OD:	3.486
Intrabeam NOHD (m):	5.48E+02

Optical Configuration: OD and NOHD

Lens Focal Length (mm):	
Beam Spatial Profile:	circular gaussian
Major Axis Diameter (mm):	
Minor Axis Diameter (mm):	
Lens-on-Laser NOHD (m):	na
Fiber Type:	none
Fiber Optic NOHD (m):	na

Diffuse Reflection: MPE, NHZ and OD

Spectral Reflectivity (%):	100
Viewing Angle (degree):	0.0
Observer Range (m):	2.5E-1
Point Source Eye NHZ (m):	1.94E-01
OD at Observer Range:	0.0
Fraction of Ocular MPE:	6.00E-01
Times Skin MPE:	4.91E-04

Laser Calculated Values

Average Power (W):	na
Peak Power (W):	3.00E+00
Energy (J):	7.50E-01
Duty Cycle (%):	1.00E+02

Aperture Calculated Values

(LA = Limiting Aperture)

LA Eye (mm):	7.0
LA Skin (mm):	3.5
Irradiance in Eye LA	
(Peak) Eye (W/cm^2):	7.80E+00
(Avg) Eye (W/cm^2):	7.80E+00

Repetitive Pulse Information

Rule Used:	na
Rule 1 MPE (J/cm^2):	na
Rule 2 MPE (J/cm^2):	na
Rule 3 MPE (J/cm^2):	na
Pulses per Exposure:	na

Correction Factors, Time Limits

Absorption (IR-A) C_A:	1.00E+00
Blue light C_B:	4.37E+01
Pre-retinal C_C:	na
Repetitive pulse C_P:	na
t_1 (s):	na