Jefferson Lab Thomas Jefferson National Accelerator Facility	# Laser Operational Safety Procedure (LOSP) Form (See ES&H Manual Chapter 6410 Appendix T1 Laser Operational Safety Procedure)

Serial Number: ______________________

(Assigned by ESH&Q Document Control x7277)

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

Issue Date:		**Expiration Date:**	
Title:	Operation of the DIRC 3B laser		
Location where the laser will be used:	EEL 108 DIRC laser room		
Description of Project	The DIRC laser will be used to evaluate synthetic fused silica bars received from SLAC for their mechanical and optical quality		
Document Owner(s): **Usually the LSS, but could be someone else**	Benedikt Zihlmann, Marc McMullen	**Date:**	10/20/2022

Laser Inventory

	Laser Serial #	Laser Class	Wavelength(s)	Maximum Power/Energy
1.	S5935	3B	325nm/442nm	14mW/44mW
2.				
3.				
4.				

Approval Signatures:	**Print**	**Signature**	**Date:**
Laser System Supervisor:	Benedikt Zihlmann		
Laser Safety Officer:	Jennifer Williams		
Division Safety Officer			
Department or Group Head:			
Other Approval(s):	**Class 4 will require Fire Protection SME**		
	Where applicable, SMEs for LTT, IH, High Voltage, etc.		

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Revision:	**Reason for revision or update:**	**Serial number of superseded document**

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

Introduction: In areas containing more than one laser, define operational sequence or parameters.

- The DIRC laser is located in EEL 108
- The operational use of the laser is to evaluate synthetic fused silica bars received from SLAC for their mechanical and optical quality
- There is a single Kimmon model IK5351R-D class 3b laser located in the LCA
- See Fig. 3 for a diagram of the LCA

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

- The LSS is Benedikt Zihlmann and the Jlab LSO is Jennifer Williams
- Laser Operators must complete the following training:
  - SAF1140 – Laser Safety Orientation
  - MED02 – Laser Eye Exam
  - SAFXXX – Laser Specific Training for the DIRC laser
  - GERT
- Will spectators be allowed? **Yes, spectators (without training) may be escorted in the LCA when the laser output is disabled**:
  - LSS approval is required
  - Spectator shall be escorted at all times by a qualified laser operator
  - Spectator shall be briefed on the hazards within the LCA and the controls in place to mitigate the hazards

  - No spectators are allowed in the room during alignment or manual measurement operations

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

The laser set up is on a 5’ wide x 10’ long optical table which is ~3’ tall. The beam path will stay level at a height of about 3 to 5 inches above the surface of the optical table. Blocking panels ensure the beam does not extent past the limits of the table top. The panels are interlocked to prevent laser output when the panels are down.

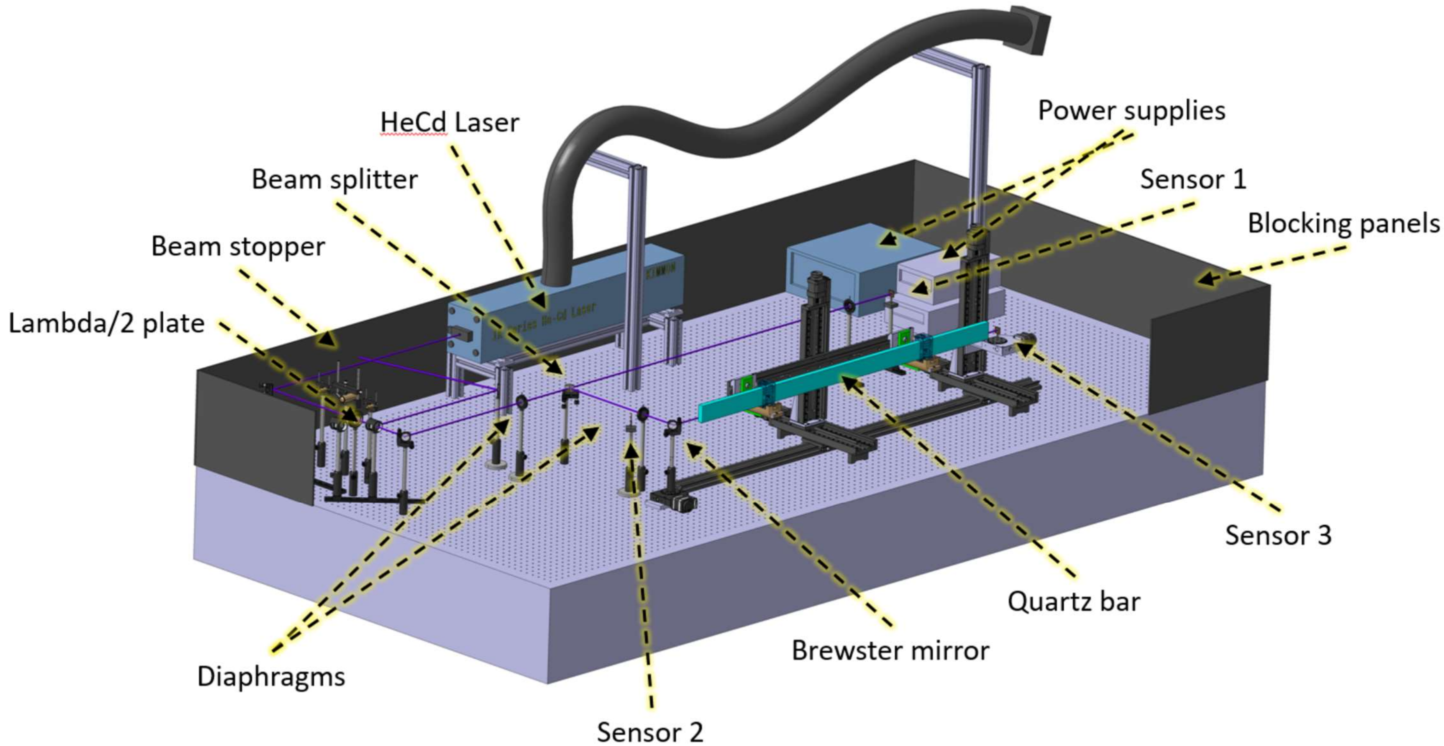


Figure 1. Optical table rendering with components. The beam path is in violet.

The schematic of the setup is shown in the figure above. All components are mounted on an optical table.

The He-Cd laser operates at two wavelengths, 325nm (“UV”) and 442nm (“blue”), which are selected with a manual switch at the front of the laser. The laser housing is mounted to the optical table at a fixed height to ensure the beam is parallel to the table surface. At the laser exit, the UV line has an output power of up to 14mW, a beam diameter below 1mm, and a beam divergence of 0.5mrad. The blue line has an output power of up to 44mW, a beam diameter below 1mm, and a beam divergence of 0.5mrad.

UV-enhanced aluminum mirrors, coated with MgF2, guide the laser beam in the optical plane, which is parallel to the table surface. The Lambda/2 plate changes the orientation of the polarization plane of the beam.

The laser beam will be 3 to 6 inches above the surface of the table (36”). All segments of the beam will terminate at either an absorber or photo diode sensor.

All walls of the LCA will have at least one emergency stop to shut off the laser output.

- List each laser in use in your LCA, include the following information (examples below):

Laser Description	Kimmon Koha IK5351R-D
Laser Type	Helium Cadmium (He-Cd)
Laser Class	Class 3B/IIIb
Laser Manufacturer	Kimmon Koha
Laser Model Number(s)	IK5351R-D
Laser Serial Number(s)	S5935
Wavelength Range	(325nm/442nm)
Power Range	14mW/44mW
Mode (i.e., time structure)	CW
Beam Diameter (collimated, typical)	0.9/1.0 mm
Divergence (uncollimated, typical)	< 0.5 mrad*2 +/- 10%
Laser Eyewear O.D.	+2

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

Hazards:

- Specular reflection – mitigated by an interlocked door, interlock system controls, Jlab-required training, and laser eye protection (O.D. 2+)
- Temporary/permanent eye damage – mitigated by an interlocked door, interlock system controls, Jlab-required training, and laser eye protection (O.D. 2+)
- HV exposure – mitigated the use of NRTL-approved equipment installed by Jlab QEW and PPE. A separate task hazard analysis is required for task involving electrical hazards.
- Chemical exposure – mitigated through the use of Jlab IH-approved cleaning chemicals, disposal practices, and PPE
- Trips/Fall – mitigated by appropriate lighting of walkways, proper housekeeping, and oversight by LSS and area safety warden
- Human error - mitigated by an interlocked door, interlock system controls, Jlab-required training, and laser eye protection (O.D. 2+)

System Experts will determine any modifications or repairs needed to any equipment. Any work needed by external vendors (i.e. laser manufacturer) shall be reviewed by the LSS prior to assignment.

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

Figure 2. Map of DIRC laser lab area

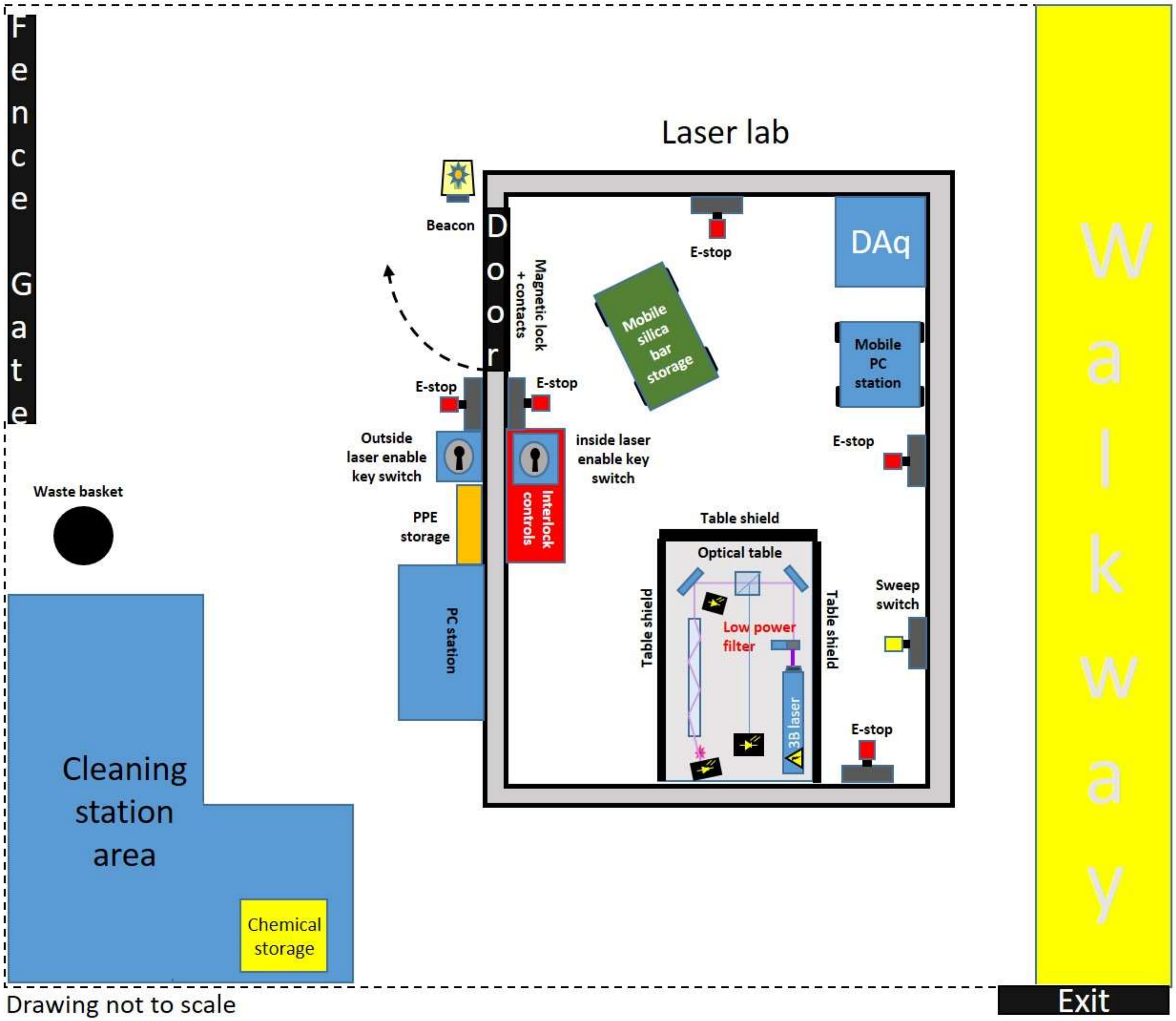
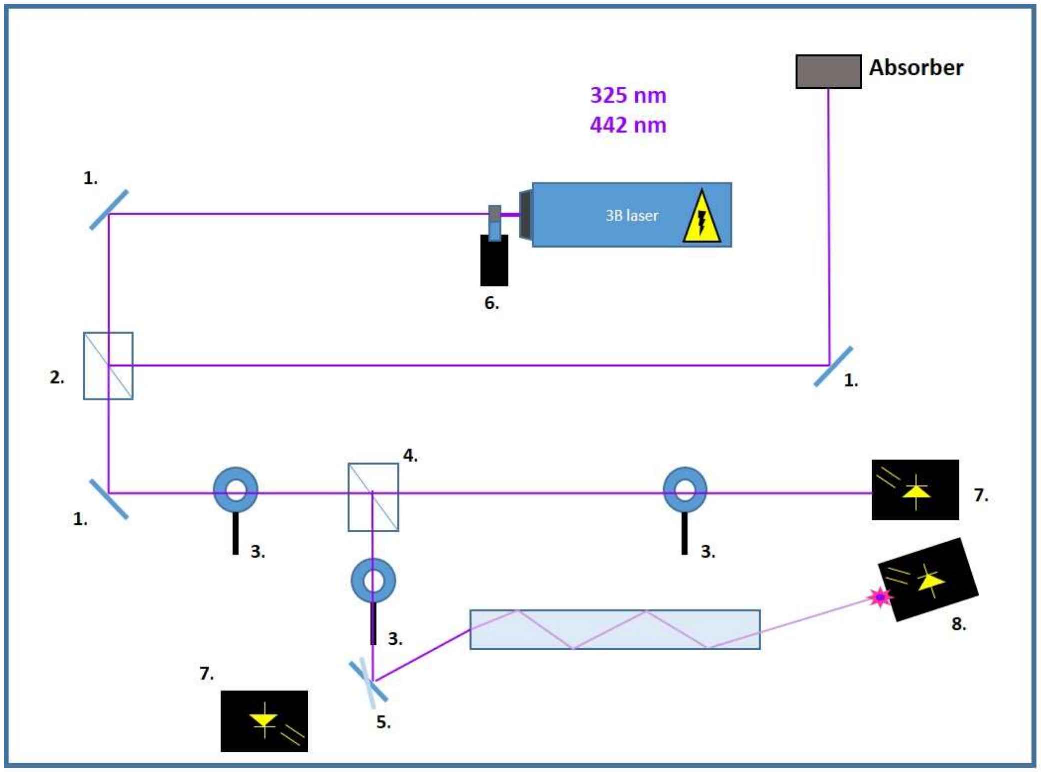


Figure 3. Optical table layout



1. Mirrors
2. Polarizing cube
3. Diaphragms
4. Beam splitter
5. Brewster mirror
6. Low power filter
7. Reference diode (x2)
8. Value diode

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

Before entry, authorized staff shall don laser eye protection and lab coats.

Initial alignment procedure (Trained staff only):

The initial alignment procedure will ensure the laser beam is controlled within the boundaries of the optical table and the beam alignment components, measurement sensors, and dump components are in the correct position.

1. Alignment of the laser requires:
    a. personnel to visually observe the laser while it is on, inside the room
    b. Key access (via the Keywatcher enclosure in the hallway of the EEL building)
    c. Sweep of the room and actuation of the “sweep” switch to confirm that the lab is ready for laser output
2. Entry into the laser lab will trigger the interlock system to disable the laser output
3. Repositioning components on the optical table is done while the laser is disabled
4. To operate the laser, configure the laser to low power mode by positioning the filter directly in front of the beam
    a. The filter will reduce laser power to less than or equal to the power of a Class 3R laser
5. The table side shields should be up/in position to stop the beam from going past the extent of the table
6. Visually confirm the status of the room (all hazards mitigated) and press the “sweep” switch
7. The final step to enable the laser is to insert the in-room key and rotate it to “output enable”
    a. The laser will be enabled
    b. Outside-room key control will be disabled

Expert Mode - Manual quartz bar measurement (Expert trained staff only):

After initial alignment, manual measurements of the quartz bars will be done by a limited number of trained staff. The LSS shall assign the designation of “expert” to persons who have demonstrated knowledge of the system and adherence to the Jlab safety protocols concerning laser operations. **Laser eye protection and lab coats must be worn at all times.**

An “expert” key will be housed in the Keywatcher enclosure, and only be available for checkout by the designated experts.

Experts shall be qualified to use the “expert” key switch position which will configure the laser to full power from the inside the room key position. Laser eye protection and lab coats must be worn at all times.

Manual quartz measurements are done with the “expert” inside the LCA, during beam-on operations, without the low-power filter in place. The table side shields will contain the laser during operations and confine the beam to the boundaries of the optical table.

After initial alignment of the laser and optical components (In low power configuration), manual measurements must be done to ensure that the quartz bar and the measurement diodes are positioned correctly for all measurement points. The quartz bar is mounted to a linear stage, which is moved by a stepper motor through the laser beam. In addition to the quartz bar stage, photodiodes are used to establish maximum laser intensity at specific positions of the optical table:

Sensors:

1. Receives half of the laser intensity after the laser is split, monitors laser intensity
2. Monitors laser intensity reflected from the face of the bar
3. Monitors laser intensity after it has passed through the front face of the bar and has reflected throughout the body of the bar (up to 55 reflections)

Automated measurement mode – (No personnel in LCA)

Automated measurement mode can be done after the optimal position of the quartz bar has been established and the position of the measurement photodiodes has been verified.

Prior to enabling the output of the laser, the operator shall perform a sweep of the laser lab. Operator actions during the sweep are as follows:

1. Enter the laser room and verify no personnel are in the room
2. Actuate the sweep switch on the wall opposite the door
3. Exit the room

Automated measurement mode is done via the operating position **outside of the LCA**. The laser is armed from the key position on the outside of the laser room after verifying that the room is clear of personnel.

Once the room and all interlock latches have been cleared, the key is inserted and the laser is armed and ready for output.

A control program will aid in the performance of the measurement. Any actuation of the door or an emergency stop will shut down the laser and latch the appropriate interlocks.

Maintenance and Service:

Maintenance of the laser system or the interlock system is not standard procedure for operating the DIRC laser. Any maintenance of the laser system or the interlock system will require a Task Hazard Analysis for that task, and potentially a Temporary Operating Safety Procedure. The LSS and LSO will be consulted and make any determinations for this work.

During standard operation or alignment of the laser equipment, personnel and equipment safety is governed by engineering controls and the procedure. During all laser operations covered in this document and the LOSP, a LOTO procedure is not required.

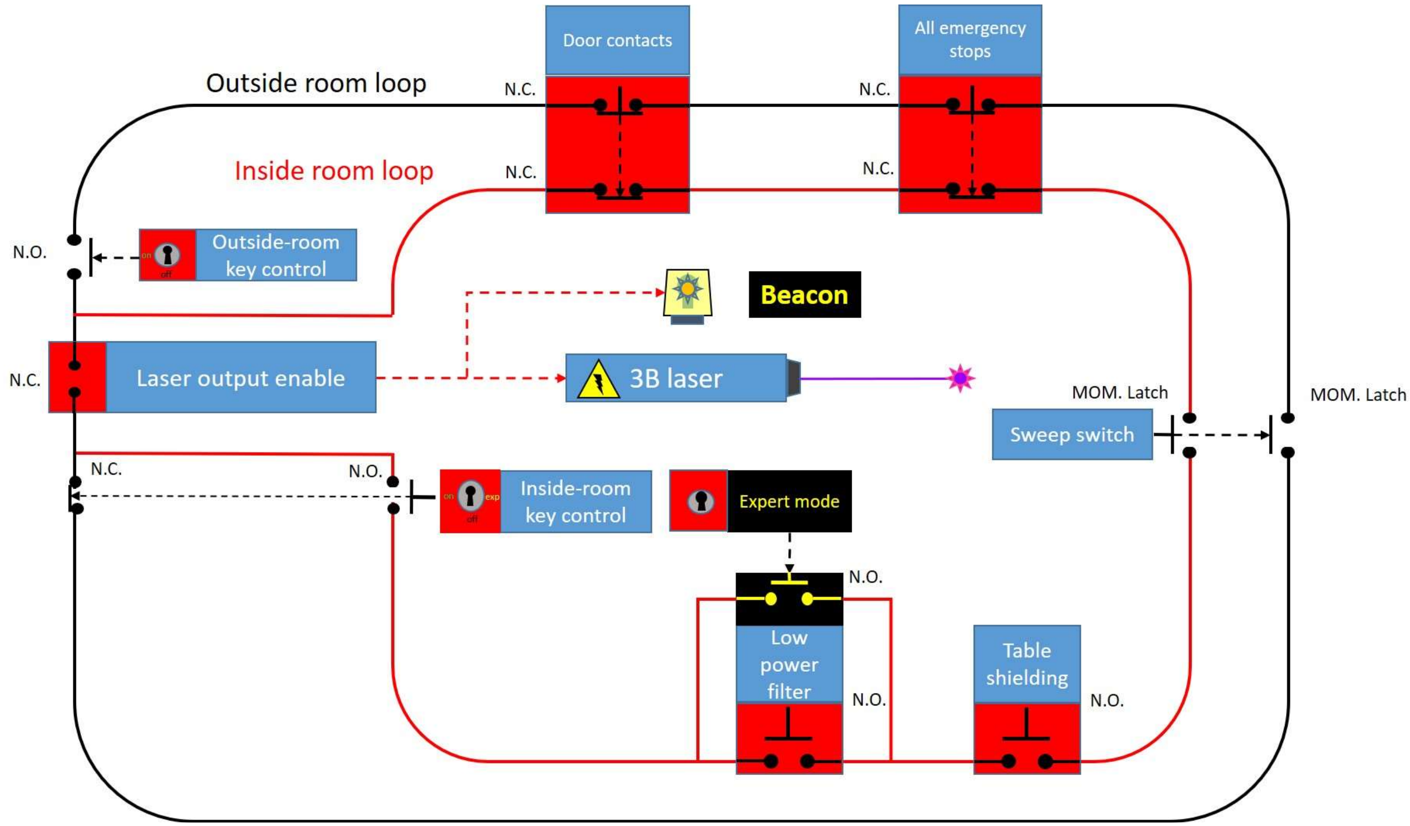
Laser Controls	Based on the information developed in the THA: • Describe all controls (administrative and engineering) required to be in place during laser operations. • If a different control is recommended, describe the rationale for not using a typical/recommended control.

An engineered control-based interlock system has been developed with the following elements:

- Key control switches
- magnetically locked door with contacts
- Emergency stop switches
- Interlock shields for the table sides prevent the laser beam from extending beyond the table
- A filter to reduce the laser power during alignment
- Latching interlock switches and contacts
- Personnel sweep switch

The system is designed to disable the laser output if any element triggers the interlock. The system is designed to latch in a way that forces the operator to affirm all interlocks are cleared before resuming laser output.

Figure 4. Laser interlocks diagram



Low power filter:

Filter: ThorLabs NE20A - Ø25 mm Absorptive ND Filter, SM1-Threaded Mount, Optical Density: 2.0

Actuator: ThorLabs MFF101 - Motorized Filter Flip Mount with Ø1" Optic Holder, 8-32 Tap

The normal position of the flip mount actuator positions the filter in the path of the laser (0 degrees). During Automated and Expert measurement modes the actuator will rotate the filter out of the path of the laser (90 degrees). Should the system lose power, the laser output would not be available and the interlocks will put the entire LCA in a safe position. When power returns, the flip mount actuator will return to the 0-degree position (in the path of the laser).

The filter will reduce the power of the laser by a factor of 100. This reduces the laser power to that of a Class 3R laser or less.

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

11/28/2022 **Laser Hazard Analysis** **ANSI Z-136.1 (2014)**

Reference: Beni Zihlmann 14 mW @ 325nm **Class: IIIb**

Location: N/A
Building: N/A
Room: N/A
LSO: N/A

Laser Detail

Laser	
Wavelength:	325 nm
Mode:	Continuous Wave
Laser Output	0.014 Watts
Pulse Energy:	N/A
Pulse Length:	N/A
Pulse Rate:	N/A
Intrabeam	
Gaussian Criteria:	1/e
Beam Shape:	Circular
Major Axis Dimension:	0.9 mm
Major Axis Divergence:	0.5 mrad
Minor Axis Dimension:	N/A
Minor Axis Divergence:	N/A
Exposure Duration:	100 Seconds
Lens On Laser	
Lens Focal Length:	3.5 mm
Beam Size at Lens:	0.9 mm
Diffuse Reflection	
Beam Size on Diffuser:	3.5 mm
Diffuser-Observer Distance:	3 Meters
Viewing Angle off Normal:	0 Degrees
Reflection Coefficient:	100 Percent
Exposure Duration	30000 Seconds
Fiber Optics	
Fiber Optics Mode:	N/A
Mode Field Diameter:	N/A
Numerical Aperture:	N/A
Known Range	
Small Source Range:	N/A

Analysis

MPE-Intrabeam Time Base (100.00 Seconds)	
Small Source MPE (Eye)	1.00E-02 W/cm²
Small Area MPE (Skin)	1.00E-02 W/cm²
MPE-Diffuse Time Base (3.00E+04 Seconds)	
Small Source MPE (Eye)	3.33E-05 W/cm²
Extended Source MPE (Eye)	N/A
Small Area Diffuse MPE (Skin)	1.00E-03 W/cm²
Nominal Hazard Zones	
Intrabeam exposure condition	2.66E+01 Meters
Lens on laser condition	5.19E-02 Meters
Small source diffuse reflections	1.16E-01 Meters
Multi-mode fiber optics	N/A
Single mode fiber optics	N/A
Small Source Intrabeam Viewing	
Average power	1.40E-02 Watts
Energy per pulse	N/A
Pulse peak power	N/A
Limiting aperture (Eye)	3.50E+00 mm
Limiting aperture (Skin)	3.50E+00 mm
Irradiance at eye	1.46E-01 W/cm²
Radiant exposure at eye	N/A
Minimum required optical density	1.16
EN-207 L Number	N/A
Filter transmittance	6.87E-02
Ocular Exposure to Diffuse Laser Radiation	
Source type	N/A
Actual viewing angle (alpha)	N/A
Limiting viewing angle (alpha-min)	N/A
Maximum large source range	N/A
Calculated exposure	N/A
Required minimum optical density	N/A
Small Source Intrabeam Viewing at Known Range	
Beam area	N/A
Calculated exposure	N/A
Minimum required optical density	N/A
Small Source Diffuse Viewing at Known Range	
Average power	1.40E-02 Watts
Energy per pulse	N/A
Minimum range	3.00E+00 Meters
Irradiance at 3 meters	4.95E-08 W/cm²
Radiant exposure at eye	N/A
Power at eye	4.76E-09 Watts
Energy at eye	N/A
Minimum required optical density	0.00
Filter transmittance	1.00E+00
Small Source Multiple Pulse Factors	
Small source effective total pulses	N/A
Multiple Pulse Correction Factor	N/A
MPE rule applied	N/A

Figure 6: Laser hazard analysis 14 mW @ 325 nm

11/28/2022 # Laser Hazard Analysis **ANSI Z-136.1 (2014)**

Reference: Beni Zihlmann 44 mW @ 442nm **Class: IIIb**

Location: N/A
Building: N/A
Room: N/A
LSO: N/A

Detail

Laser		**Lens On Laser**	
Wavelength:	442 nm	Lens Focal Length:	7 mm
Mode:	Continuous Wave	Beam Size at Lens:	0.9 mm
Laser Output	0.044 Watts	**Diffuse Reflection**	
Pulse Energy:	N/A	Beam Size on Diffuser:	7 mm
Pulse Length:	N/A	Diffuser-Observer Distance:	3 Meters
Pulse Rate:	N/A	Viewing Angle off Normal:	0 Degrees
Intrabeam		Reflection Coefficient:	100 Percent
Gaussian Criteria:	1/e	Exposure Duration	600 Seconds
Beam Shape:	Circular	**Fiber Optics**	
Major Axis Dimension:	1 mm	Fiber Optics Mode:	N/A
Major Axis Divergence:	0.5 mrad	Mode Field Diameter:	N/A
Minor Axis Dimension:	N/A	Numerical Aperture:	N/A
Minor Axis Divergence:	N/A	**Known Range**	
ExposureDuration:	0.25 Seconds	Small Source Range:	N/A

Analysis

MPE-Intrabeam Time Base (0.25 Seconds)		**Ocular Exposure to Diffuse Laser Radiation**	
Small Source MPE (Eye)	2.55E-03 W/cm²	Source type	Extended
Small Area MPE (Skin)	3.11E+00 W/cm²	Actual viewing angle (alpha)	2.33E+00 mrad
MPE-Diffuse Time Base (6.00E+02 Seconds)		Limiting viewing angle (alpha-min)	1.50E+00 mrad
Small Source MPE (Eye)	1.00E-04 W/cm²	Maximum large source range	4.67E+00 Meters
Extended Source MPE (Eye)	1.00E-04 W/cm²	Calculated exposure	1.55E-07 W/cm²
Small Area Diffuse MPE (Skin)	2.00E-01 W/cm²	Required minimum optical density	0.00
Nominal Hazard Zones		**Small Source Intrabeam Viewing at Known Range**	
Intrabeam exposure condition	9.38E+01 Meters	Beam area	N/A
Lens on laser condition	3.65E-01 Meters	Calculated exposure	N/A
Small source diffuse reflections		Minimum required optical density	N/A
* R1 > 4.67E+00 meters	1.18E-01 Meters	**Small Source Diffuse Viewing at Known Range**	
Multi-mode fiber optics	N/A	Average power	4.40E-02 Watts
Single mode fiber optics	N/A	Energy per pulse	N/A
Small Source Intrabeam Viewing		Minimum range	3.00E+00 Meters
Average power	4.40E-02 Watts	Irradiance at 3 meters	1.56E-07 W/cm²
Energy per pulse	N/A	Radiant exposure at eye	N/A
Pulse peak power	N/A	Power at eye	5.99E-08 Watts
Limiting aperture (Eye)	7.00E+00 mm	Energy at eye	N/A
Limiting aperture (Skin)	3.50E+00 mm	Minimum required optical density	0.00
Irradiance at eye	1.14E-01 W/cm²	Filter transmittance	1.00E+00
Radiant exposure at eye	N/A	**Small Source Multiple Pulse Factors**	
Minimum required optical density	1.65	Small source effective total pulses	N/A
EN-207 L Number	N/A	Multiple Pulse Correction Factor	N/A
Filter transmittance	2.23E-02	MPE rule applied	N/A

Figure 7: Laser hazard analysis 44 mW @ 442 nm

Minimum required optical density is 2+ at both 325 nm and 442 nm.
O.D. results confirmed with Laser Institute of American Evaluator online software.

- Signage will be posted for a Class 3B/IIIb laser at the entry way of the area and doorway into the LCA

Labeling/Posting	
See ES&H Manual Chapter 6410 Appendix T6 Laser Labeling/Posting Requirements	• Equipment/area labeling/posting requirements • Area signs

Authorized/Trained Individuals	
Print Name/Signature	**Date**