SUBJECT AREA CONTENT

Management System: Worker Safety and Health			
Subject Area: Laser Safety **VIEW/PRINT ALL (No Exhibits and Forms)**			
Effective Date: **Jan 23, 2015** (Rev 4.0) Periodic Review Due: **Jan 23, 2020**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak	Management System Steward: Gail Mattson

Introduction

The subject area provides procedures and guidelines for working with lasers at Brookhaven National Laboratory (BNL) that conform to ANSI Z136.1-2007, American National Standard for the Safe Use of Lasers. The subject area is not a restatement of the standard, although reference copies of the full standard are available from the research library or the Laser Safety Officer.

The section Ensuring Worker Qualification addresses specific training needs for users/operators of lasers. The ANSI standard calls for safety awareness training for all who work in or around lasers, not only those who work with lasers. Others, such as custodians who may need to access laser controlled areas but will not work on or with lasers, must be provided with awareness level training (TQ-LASER-NU). See the BNL Training and Qualifications Web site for course information.

The potentially more hazardous Class 3B and 4 laser systems are emphasized, but requirements for all lasers used at BNL are covered in this subject area. Exhibits that illustrate the implementation of the Laser Safety Program for different types of installations at BNL are included. The exhibit Bibliography of Laser-related Resources is also provided for reference. Because of the nature and complexity of laser operations, it is Laboratory policy to have a dedicated Laser Tier I inspection program, which targets these areas, emphasizing an overview of laser operations in each laboratory/area semiannually. The section Inspecting the Laser Laboratory describes the procedures for this program.

The Laser Commissioning Process Flowchart shows the path for commissioning and operating lasers at BNL. It is highly recommended that laser owners/operators seek assistance from the Laser Safety Officer early in the planning process for a laser installation. The LSO is assisted by the Associate Laser Safety Officer (ALSO) who together have the general responsibility for oversight of Laser Safety.

Contents

Section	Overview of Content (see section for full process)

1. Conducting the Safety Hazard Analysis	• Notify Line Manager and F&O Facility Project Manager. • Classify laser output or system and register lasers. • Evaluate risk posed by laser hazards. • Determine engineered and administrative controls to mitigate risk.
2. Developing the Laser Controlled Area Documentation	• Identify controls to be documented. • Register Class 3B and 4 lasers. • Revise the existing Laser Controlled Area SOP or develop a new one. • Annually review Laser Controlled Area SOP.
3. Using Low Power Lasers	• Register lasers. • Complete the BNL Low Power Laser Use Permit Form and review with LSO. • Obtain signs and post the area.
4. Installing Laser Equipment	• Determine if a facility modification permit or engineered design is required. • Notify F&O Facility Project Manager of the intent to install laser. • Install laser in conformance with controls and regulations. • Ensure that laser radiation is controlled within established NHZ. • Verify that administrative and engineering controls are in place.
5. Ensuring Worker Qualification	• Schedule laser eye examination. • Complete medical history and examination form. • Complete training.
6. Wearing Personal Protective Equipment	• Use eyewear and skin protection.
7. Inspecting the Laser Laboratory	• Inspect all laser laboratories every six months (SOP-authorized locations). • Complete checklist. • Resolve corrective actions, and sign, date, and return checklist.

Definitions

Exhibits

Alignment Guidelines (Example Format)
Bibliography of Laser-related Resources

Biology Alignment Practice
Collider Accelerator Department (CAD) EEMC Laser Alignment
Engineered and Administrative Control Matrix
Examples of Standard Operating Procedures (SOPs) from Working Laboratories
General Guidance for Laser Protective Eyewear
Guidance on Interlock Systems for Lasers
Guidelines for Laser Pointer Safety
Hazards Associated with Using Lasers
Instrumentation Ti-Sapp Operation
Instrumentation YAG Operation
Laser Commissioning Process Flowchart
Laser Electron Accelerator Facility (LEAF) Working Procedures
Laser Lab Interlock Instrumentation Test Procedure
Laser Safety Instructions (BNL Chemistry Example)

Forms

BNL General Laser Registration Form
BNL Low Power Laser Use Permit
Laser Controlled Area Standard Operating Procedure (SOP)
Laser System - Specific Training Checklist
Laser User Medical History and Examination Form with Instructions
Laser User Qualification Form
Semiannual Laser Safety Inspection and Action Item Checklist
System Training Log

Training Requirements and Reporting Obligations

This subject area contains training requirements in the section Ensuring Worker Qualification. See the Training and Qualifications Web Site.

This subject area does not contain reporting obligations.

External/Internal Requirements

Requirement Number	Requirement Title
10 CFR 830, Subpart A	Energy, Nuclear Safety Management, Quality Assurance Requirements
10 CFR 851	Worker Safety and Health Program
29 CFR 1910	Labor/Occupational Safety and Health Standards
ANSI Z 136.1	Safe Use of Lasers
BSA Contract No. DE-SC0012704 - Clause I.131 DEAR 970.5223-1)	Integration Of Environment, Safety, And Health Into Work Planning And Execution (dec 2000)
O 414.1D Admin Chg 1 (May 8, 2013)	Quality Assurance

References

American National Standards Institute (ANSI), American National Standard for the Safe Use of Lasers. ANSI Z136.1-2007, Laser Institute of America, Orlando, FL.

BNL Training and Qualifications Web Site

Electrical Safety Subject Area

Environment, Safety, Health and Quality (Tier I) Inspections Subject Area

Event/Issues Management Subject Area

Lockout/Tagout (LOTO) Subject Area

Occurrence Reporting and Processing System (ORPS) Subject Area

Work Planning and Control for Experiments and Operations Subject Area

Standards of Performance

Management systems, standards, implementing procedures, and guidelines shall be developed with appropriate input from staff enabling them to effectively work in compliance with applicable requirements.

All staff and guests shall ensure that personnel radiation exposure is maintained As Low As Reasonably Achievable (ALARA).

All staff and guests shall comply with applicable Laboratory policies, standards, and procedures, unless a formal variance is obtained.

All staff and users shall identify, evaluate, and control hazards in order to ensure that work is conducted safely and in a manner that protects the environment and the public.

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Before using a printed copy, verify that it is the most current version by checking the *effective date*.

PROCEDURE: CONDUCTING THE SAFETY HAZARD ANALYSIS

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
1. Conducting the Safety Hazard Analysis		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to all staff who design and/or set up workplaces where lasers are to be used.

Required Procedure

When controlling workplace stressors, the process for determining feasible and effective controls is to be based on the following hierarchy of controls:

- Elimination
- Substitution
- Engineering controls
- Administrative controls
- Personal protective equipment.

The best controls are those that eliminate the hazard, followed by those that control the source or shield the worker from the source. Next in the hierarchy is work planning that limits a worker's exposure to the source. The least desirable approach is controlling exposure at the worker's location, especially the use of protective equipment worn by the worker.

Staff planning an operation involving the use of a laser must provide for a workspace with appropriate engineered and administrative controls. Refer to the Work Planning and Control for Experiments and Operations Subject Area when planning experimental work, as well as the Electrical Safety Subject Area. The (Associate) Laser Safety Officer must consider hazards created by ergonomic principles in laser system designs, such as poor workstation layout, experimental configuration, worker-experiment interface, manual handling techniques, and area illumination.

Step 1	Notify Line Managers and F&O Facility Project Manager, where applicable, of the workspace during the preparation of all safety hazard analyses. The Line Manager and F&O Facility Project Manager may allow or deny the planned use of selected workplaces for specific applications and systems. **Note:** Appeals may be made to Line Managers and F&O Facility Complex

	Managers.
Step 2	Characterize the laser output and determine the classification of the laser or laser system. Keep in mind that lasers that have embedded Class 3B or 4 lasers may be Class 1 in normal operation, but may need to be evaluated at the 3B or 4 level for potential hazards when open for maintenance or alignment.
Step 3	Register the lasers to be used by completing the BNL General Laser Registration Form. Operations for lasers below Class 3B outside of a normal Laser Controlled Area can be addressed through the use of the BNL Low Power Laser Use Permit. Send both forms to the Laser Safety Officer.
Step 4	Identify associated nonlaser hazards. See the exhibit Hazards Associated with Using Lasers.
Step 5	Evaluate the risk posed by the laser hazards. For Class 3B and 4 lasers, complete the Laser Controlled Area Standard Operating Procedure, in consultation with the Laser Safety Officer.
Step 6	Using the exhibit Engineered and Administrative Control Matrix, determine engineered and administrative controls that would mitigate unacceptable risk. Evaluate the costs and benefits. **Note:** If you use interlocks, follow the Electrical Safety Subject Area. For more information on interlocks, consult with the Laser Safety Officer and see the exhibit Guidance on Interlock Systems for Lasers.

Guidelines

When selecting a workplace where lasers will be used, staff may first want to identify available workspace with existing engineered controls in place to minimize modification investment. When selecting space, consider the following factors:

- Spaces already set up for lasers containing
  - a laser interlock system;
  - ANSI-compliant signs;
  - light enclosure to control laser light to the working area;
- Accommodation of area to bench layout requirements of laser;
- Risks to others present.

The following exhibits may be useful:

Engineered and Administrative Control Matrix

Guidance on Interlock Systems for Lasers

References

Electrical Safety Subject Area

Work Planning and Control for Experiments and Operations Subject Area

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https://sbms.bnl.gov/sbmsearch/subjarea/113/113_pro1.cfm

PROCEDURE: DEVELOPING THE LASER CONTROLLED AREA DOCUMENTATION

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
2. Developing the Laser Controlled Area Documentation		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to staff who are involved in operations utilizing Class 3B or 4 lasers.

Required Procedure

A BNL Laser Controlled Area Standard Operating Procedure (SOP) must be developed. It is a key safety document that must be consistent with the guidance provided in the subject area. The SOP must include appropriately detailed information on configuration, administrative controls, engineering controls, personal protective equipment, and staff training requirements. Revisions to existing documentation must follow the format of the SOP. The exhibit Examples of Standard Operating Procedures (SOPs) from Working Laboratories provides representative examples from laser installations at BNL.

Step 1	Using hazards analysis information and consequent engineering and administrative controls identified from the hazards analysis (see the section Conducting the Safety Hazard Analysis), identify those controls that need to be documented in a laser controlled area standard operating procedure (SOP).
Step 2	For Class 3B and 4 lasers, register the lasers on the BNL General Laser Registration Form.
Step 3	Revise the existing Laser Controlled Area SOP, if appropriate, or develop a new Laser Controlled Area SOP, making sure to include the following • The safe operating envelope for anticipated configurations and operating modes (routine operation, maintenance including alignments, and service), where appropriate; • Requirements for worker qualification (see the section on Ensuring Worker Qualification); • Approval signatures of the Line Manager, Environmental Safety and Health

	Coordinator, and Laser Safety Officer.
Step 4	Annually review the Laser Controlled Area SOP to ensure that it accurately reflects current activities.

Guidelines

The use of working procedure documents separate from the Laser Controlled Area SOP is encouraged as long as they do not modify the safety envelope of the installation. Documents of this type provide a useful reminder of working practices as well as an important training aid. Some examples of laboratory working procedures are provided by the following exhibits:

Alignment Guidelines (Example Format)

Biology Alignment Practice

Collider-Accelerator Department (CAD) EEMC Laser Alignment

Instrumentation Ti:Sapp Operation

Instrumentation YAG Operation

Laser-Electron Accelerator Facility (LEAF) Working Procedures

Laser Safety Inspection (BES Example)

The only official copy of this file is the one on-line in SBMS.

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https://sbms.bnl.gov/sbmsearch/subjarea/113/113_pro2.cfm

PROCEDURE: USING LOW POWER LASERS

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
3. Using Low Power Lasers		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to all staff who operate Class 1M, 2, 2M, 3A (legacy designation), or 3R lasers.

Required Procedure

Although laser pointers used as presentation/lecture aids are exempt from any registration/permitting requirements, staff are required to utilize them safely and responsibly. Individuals are encouraged to purchase/use class 2 laser pointers (≤1 milliwatt) over class 3A/R laser pointers. See the exhibit Guidelines for Laser Pointer Safety for guidelines on use.

Step 1	Register low power lasers using the BNL General Laser Registration Form. If the laser is to be used outside a laser controlled area approved for Class 3B or 4 lasers, continue to steps 2 and 3.
Step 2	Complete the BNL Low Power Laser Use Permit and review it with the Laser Safety Officer. The Laser Owner/Operator retains the original form. The Laser Safety Officer retains the copy.
Step 3	Obtain the appropriate signs for the area from the Laser Safety Officer, and post the area.

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https://sbms.bnl.gov/sbmsearch/subjarea/113/113_pro3.cfm

PROCEDURE: INSTALLING LASER EQUIPMENT

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
4. Installing Laser Equipment		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to staff who set up and/or install Class 3B or 4 lasers.

Required Procedure

Staff must ensure that the laser, laser hardware, and laser safety engineered controls are consistent with the guidelines in the exhibit Engineered and Administrative Control Matrix.

Step 1	Notify the F&O Facility Project Manager of the intent to install the laser system.
Step 2	Determine if a facility modification permit or engineered design is required.
Step 3	Install the laser to operate in conformance to the engineered and administrative controls identified for this laser operation (see the section Conducting the Safety Hazard Analysis), and in accordance with ANSI-Z136.1-2007, American National Standard for the Safe Use of Lasers.
Step 4	Where appropriate, install laser such that laser radiation above the maximum permissible exposure is limited to the laser table. Otherwise, ensure that laser radiation is controlled within the established Nominal Hazard Zone (NHZ) control area. A combination of opaque barriers, filters, beam stops, etc., will be used to ensure personnel safety. Any unwanted primary or specular beams will be terminated in a beam stop that does not produce hazardous diffuse reflections.
Step 5	Ensure that all administrative and engineering controls are in place.
Step 6	The Laser Safety Officer reviews and approves the laser configuration and installation.

References

American National Standards Institute (ANSI), American National Standard for the Safe Use of Lasers. ANSI Z136.1-2007, Laser Institute of America, Orlando, FL.

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https://sbms.bnl.gov/sbmsearch/subjarea/113/113_pro4.cfm

PROCEDURE: ENSURING WORKER QUALIFICATION

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
5. Ensuring Worker Qualification		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to BNL staff and non-BNL staff who operate Class 3B and 4 lasers. It also applies to staff who supervise users of lasers or laser systems.

Required Procedure

Ensuring Worker Qualification contains two subsections:

5.1 Medical Evaluations
5.2 Laser Safety Training

Staff using or supervising users of lasers or laser systems must meet medical and training qualification requirements consistent with ANSI Z136.1- 2007, American National Standard for the Safe Use of Lasers.

5.1 Medical Evaluations

Baseline medical eye examinations are required and provided for individuals working with or in an area of Class 3B or 4 lasers. When an examination is required, a user must receive the examination before participating in laser work. Pertinent examinations are repeated following any suspected laser injury.

Step 1	The Line Manager identifies staff requiring laser medical examinations based on potential exposure to Class 3B or 4 laser radiation.
Step 2	The line manager provides each user requiring a laser eye exam with a Laser User Medical History and Examination Form with Instructions.

Step 3	The user completes Part A of the Laser User Medical History and Examination Form with Instructions and contacts one of the contracted local ophthalmologists listed on the form instructions to schedule a baseline laser eye examination. The ophthalmologist records the eye exam on Part B of the form and forwards both parts of the completed form to the BNL Occupational Medicine Clinic (OMC). Staff, off-site personnel, guests, and students, who are resident laser users, may obtain laser eye examinations through ophthalmologists other than those listed. The ophthalmologist's exam should be recorded on Part B of the Laser User Medical History and Examination Form with Instructions. Users who have had a recent laser eye exam can fax or mail a copy of this exam to OMC, accompanied by a completed part A of the Laser User Medical History and Examination Form with Instructions, in lieu of a new exam. OMC reserves the right to reject forms that are too old or do not meet the minimal requirements of ANSI Z136.1- 2007. In general, an acceptable substitute exam must be no more than 3 years old and have substantially the same content as Part B of the Laser User Medical History and Examination Form with Instructions.
Step 4	OMC reviews the information it receives and contacts the user if any additional information or examinations are needed. When all requirements are met, OMC notifies the Training and Qualifications Program Office that the protocol has been completed.
Step 5	The Line Manager ensures that requirements for laser medical examinations are met before the user begins laser operations.
Step 6	The user must report any injury/exposure involving lasers to their Line Manager and report to the OMC. Line management ensures that injury/exposure reporting and any incident investigation and action plans following a known or suspected incident follow the Event/Issues Management Subject Area and the Occurrence Reporting and Processing System (ORPS) Subject Area.

5.2 Laser Safety Training

Both basic and job-specific laser safety training are required and provided for laser users and temporary visitors, or guest laser users working in a Class 3B and Class 4 laser controlled area. Basic laser safety training and job-specific training must be retaken every 2 years.

Step 1	The Line Manager must ensure that staff have met requirements for basic laser safety training, as described in step 2, before they participate in laser work.
Step 2	**Basic Laser Safety Training** Ensure each resident laser user, temporary visitor, or guest completes the awareness level web-based training course TQ-LASER before beginning work (see the BNL Training and Qualifications Web Site).

Step 3	**Job-Specific Training** The Laser Owner/Operator ensures that adequate training has been provided to laser users for operating the lasers for which they are responsible. The Laser Owner/Operator conducts an orientation for the trainee of the laser operation and its controlled area requirements. Completion of training is documented using a System Training Log maintained by the Laser Owner(s)/Operator(s). Custodial staff who may need to enter laser controlled areas, but will not operate or use a laser, complete the training course TQ-LASER-NU. See the BNL Training and Qualifications Web site.

Guidelines

The following exhibits are examples of tools for tracking the training of laser users and can be used to assist in developing a training program for new installations:

Laser System-Specific Training Checklist

Laser User Qualification Form

References

American National Standards Institute (ANSI), American National Standard for the Safe Use of Lasers. ANSI Z136.1-2007, Laser Institute of America, Orlando, FL.

BNL Training and Qualifications Web Site

Event/Issues Management Subject Area

Occurrence Reporting and Processing System (ORPS) Subject Area

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PROCEDURE: WEARING PERSONAL PROTECTIVE EQUIPMENT

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
6. Wearing Personal Protective Equipment		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to all staff who operate Class 3B or 4 lasers.

Required Procedure

Step 1	Each staff member identifies specification and usage requirements for laser safety eyewear as described in the exhibit Laser Controlled Area Standard Operating Procedure (SOP).
Step 2	The Line Manager ensures that the laser safety eyewear identified is of the appropriate optical density and covers the appropriate wavelength produced by the laser. Staff must wear laser safety eyewear, where appropriate, to reduce risk of eye injury. For information on protective eyewear, refer to the exhibit General Guidance for Laser Protective Eyewear.
Step 3	The Line Manager ensures that skin protection in the form of clothing or screening lotion is provided for staff, where appropriate. Staff must wear skin protection to reduce exposure to laser radiation to skin where applicable.

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Questions/Comments Disclaimer

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PROCEDURE: INSPECTING THE LASER LABORATORY

Management System: Worker Safety and Health		
Subject Area: Laser Safety		
7. Inspecting the Laser Laboratory		
Effective Date: **Jan 23, 2015**	Subject Matter Expert: Christopher Weilandics	Management System Executive: Ed Nowak

Applicability

This information applies to BNL staff and non-BNL staff who participate in Laser Tier I Inspections.

Required Procedure

The Laser Tier I Inspections are conducted similarly (but in addition) to the Departmental Environment, Safety, Health, and Quality Tier I Inspections. See the Environment, Safety, Health and Quality (Tier I) Inspections Subject Area. However, Laser Tier I Inspections are done twice a year instead of quarterly; they have the same periodicity as required interlock testing for those laser controlled areas so outfitted. Laser Tier I Inspections are designed to emphasize an overview of the laser operations within each laboratory/area. However, these areas also need to be inspected quarterly as required by the Environment, Safety, Health and Quality (Tier I) Inspections Subject Area.

Laser Tier I Inspections are useful for the following reasons:

1. They allow Department/Division Management the opportunity to become more involved in an inspection process that very often has been conducted solely between the Laser Safety Officer and the Principal Investigator.
2. They can serve as a forum for discussion and exchange of ideas, giving the participating staff and the Laser Safety Officer a chance to interact and discuss issues related to laser safety. This interaction can educate the rest of the staff regarding laser issues.
3. They can be scheduled to take advantage of people's schedules and maximize participation of relevant staff.

Step 1	The Laser Safety Officer (LSO) ensures the quorum of the Inspection Team meets. In addition to the LSO or ALSO, the minimum recommended members would be the Principal Investigator and another Department/Division staff member ((e.g., Safety Coordinator) to coordinate the inspections and internally track action items that might result. Users of the lasers are encouraged to participate as well. Other participants may be the Facility Support Representative and technical and administrative staff.

Step 2	Laser Tier I Inspections (LSI) must be conducted for all laser laboratories located in the Department/Division. A laser laboratory is defined as any laboratory for which a BNL Standard Operating Procedure (SOP) has been authorized. The LSI consists of (1) confirmation that all laser-specific documentation, including SOPs, laser registrations, interlock tests, and laser-specific training forms, are current, (2) inspection of the lab, and (3) discussion of any changes made in documentation, operations, personnel, and equipment since the previous LSI. The Inspection Team conducts the inspection and completes the Semiannual Laser Safety Inspection and Action Item Checklist. The Team documents on the checklist where the laboratory documentation, experimental configuration, or operations are found to be noncompliant, and indicates corrective actions. **Note:** The Department/Division retains the completed checklist. The Laser Safety Officer gives each team member a copy.
Step 3	When a corrective or other action is required, the Laser Owner/Operator • Confirms that the specified action(s) is(are) completed; • Signs and dates the checklist; • Returns the checklist to the Department/Division. Failure to return the completed checklist may result in suspension of operations until compliance can be demonstrated.

References

Environment, Safety, Health and Quality (Tier I) Inspections Subject Area

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DEFINITIONS

Definition: Laser Safety

Term	Definition
Class 1 laser	A type of laser that is incapable of emitting damaging radiation levels, except for embedded Class 3b or Class 4 lasers.
Class 2 laser	A laser system that has a low hazard potential because of the expected aversion response. There is some possibility of injury if stared at longer than the 1/4-second aversion response.
Class 3a laser	A laser or laser system that normally cannot produce a hazard if viewed for only momentary periods with the unaided eye. Class 3a lasers can present a more serious hazard if viewed through collecting optics such as a microscope or telescope.
Class 3b laser	A laser that has a moderate hazard category. Class 3b lasers may cause retinal damage if the energy is collected and focused into the eye or if viewed directly. Mirror-like (specular) reflection of the beam is also considered hazardous. Class 3b lasers also may present a minor skin hazard. They do not produce hazardous diffuse reflections except at very close viewing distances.
Class 4 laser	Those systems that emit radiation, either directly or by diffuse reflection, that may be hazardous to personnel or constitute a fire hazard. These systems require the use of controls that prevent exposure of the eye and skin or other unwanted targets to specular or diffuse reflections of the beam. These lasers have a high hazard category.
Controlled Area	An area where the presence and activities of personnel are subject to control and/or supervision to protect them from the laser beam and its associated hazards.
F&O Facility Project Manager	Manages and operates specific facility(s) within a designated complex area, related equipment and systems; ensuring resolution of problems, maintaining safe and reliable operations. Serves as the single point of contact for the execution of the obligations agreed to between the approving parties of the Facility Use Agreements (FUA). **Note:** This is not a one to one replacement of all the responsibilities of the former Building Manager, but contains many of the Building Managers' responsibilities as described in the Building Manager R2A2.

laser owner/operator	The individual responsible for the laser or laser system and who controls the use, repair, and alignment of the laser. The individual is the custodian of the laser.
Laser Safety Officer	The individual who has authority to monitor and enforce measures to control laser hazards and effect the knowledgeable evaluation and control of laser hazards.
laser user	The individual conducting hands-on work with the laser equipment. This may be an individual using the laser under the guidance of the laser operator.
maximum permissible exposure (MPE)	The level of laser radiation to which a person may be exposed without experiencing hazardous effects or adverse biological changes in the eye or skin. (The MPE is determined by the criteria specified in Section 8 of ANSI Z136.1 - 2000).
nominal hazard zone (NHZ)	The space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.
resident laser users	Resident staff that are full- or part-time BNL employees or resident visitors, such as post-doctorate and visiting alumni, who are resident at the BNL campus for periods of 6 weeks or longer per year.
temporary guest users	Temporary visitors/guests who are not BNL employees, or BNL employees who are resident at the BNL campus for less than 6 weeks per year.

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Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Alignment Guidelines (Example Format)

Effective Date:**Jan 23, 2015**

Written standard alignment procedures are required for Class 3B and 4 lasers. Alignment of laser optical systems must be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to a level above the applicable Maximum Permissible Exposure.

Alignment Guidelines (Example Format) is provided below and as a Word file as an example of a format for an alignment procedure. It includes the type of information that should be considered when formulating alignment procedures for installations at BNL.

ALIGNMENT GUIDELINES (EXAMPLE FORMAT)

Appendix A
Laser Alignment Procedure
David Taylor, CLSO,
LSO Lawrence Livermore National Laboratory

Note: The RI/DLSOs are free to edit verbiage and choose which points to include and tailor to their setup in the "Procedural Considerations" and the "Alignment Methods to be used for this laser" sections only. Leave the intro line and paragraph below. It is intended that this wording below be either 1) included into the body of an OSP, 2) as an appendix, 3) attached to the IWS, 4) or as a stand-alone document. In all cases, it must be reviewed by the Responsible Individual (and possibly signed off by the LSO/DLSO) periodically, at a minimum annually or as operations change). **Delete this paragraph before you finalize the procedure. Don't forget to edit the header above.**

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. (This statement must remain. Do not delete.)
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 settings during alignment as much as is practical.
4. Laser Protective Eyewear shall be worn at all times during the alignment, within the parameters and notes established on the accompanying laser table.
5. (This paragraph must be accepted or deleted in it's entirety) The LSO has authorized reduced optical density eyewear to allow the beam spot to be seen. Measures shall be taken and documented to ensure that no stray hazardous specular reflections are present before the lower OD eyewear is worn. A return to the Maximum OD eyewear as listed in the laser table will be made when the alignment is complete. The eyewear is labeled as alignment eyewear and is stored in a different location than the standard laser eyewear for this operation.
6. Skin protection should be worn on the face, hands and arms when aligning at UV wavelengths.
7. 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.
8. Areas where the beam leaves the horizontal plane must be labeled.
9. Any stray or unused beams are terminated.
10. 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.
11. Pulsed lasers are aligned by firing single pulses when practical.
12. 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.
13. Normal laser hazard controls must be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.

This document is to be reviewed in one year from the date of the OSP/IWS, or as conditions warrant, which ever is the shorter time period

Reviewed by:

_____

LSO/DLSO Date

Approved/Reviewed/Revised by

_____

Responsible Individual Date

The only official copy of this file is the one on-line in SBMS.

Before using a printed copy, verify that it is the most current version by checking the *effective date*.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Bibliography of Laser-related Resources

Effective Date:**Jan 23, 2015**

American Conference of Governmental Industrial Hygienists (ACGIH). 1990. *A Guide for Control of Laser Hazards*. ACGIH, Cincinnati, OH.

Barat, K., ed., 2009. Laser Safety: Tools and Training. CRC Press, Taylor and Francis Group, Boca Raton, FL.

Barat, K., 2006. Laser Safety Management. CRC Press, Taylor and Francis Group, Boca Raton, FL.

Bell, R.L. 1975. *ABC's of Laser Safety*. Auburn University, Auburn, AL. Electro Optics System Design. "Electrical Hazards of Lasers." 7(12).

Marshall, W., Sliney, D. eds.,. 2000. *Laser Safety Guide,* Laser Institute of America, Baltimore, MD.

Matthew, L., and G. Garcia. 1997. *Laser and Eye Safety in the Laboratory*. Institute of Electrical and Electronics Engineers, Inc., IEEE Press, Piscataway, NJ.

Rockwell, R.J., Jr. 1981. *Laser Safety - Hazard, Inspection and Control*. Laser Institute of America, Toledo, OH.

Sliney, D., and M. Walbarsht. 1980. *Safety with Lasers and Other Optical Sources, A Comprehensive Handbook.* Plenum Press, New York, NY. Out of print, limited availability.

U.S. Department of Energy (DOE). *Worker Protection Management for DOE Federal and Contractor Employees.* DOE Order 440.1A, approved 3/27/04.

U.S. Department of Health, Education and Welfare (HEW). 1970. *Biological Aspects of Ultraviolet Radiation, A Review of Hazards.* BRH/DBE 70-3, Washington, DC.

U.S. Department of Health, Education and Welfare (HEW). 1976. *Radiation Safety Handbook for Ionizing and Non-Ionizing Radiation.* HEW Pub. (FDA) 77-8007, Washington, DC.

U.S. Department of Health, Education and Welfare (HEW). 1973. *A Review of Selected Bio-Effects Thresholds for Various Spectral Ranges of Light.* HEW Pub. (FDA) 74-8010, Washington, DC.

U.S. Occupational Safety and Health Administration (OSHA). 1991. *Guidelines for Laser Safety and Hazard Assessment.* OSHA Instruction Pub 8-1.7, Washington, DC.

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Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Biology Alignment Practice

Effective Date:**Jan 23, 2015**

Biology Alignment Practice is provided on this page and as a Word file.

Laser Alignment Fundamentals - Class 3B and 4 Lasers

Prealignment Procedures:

- Remove all jewelry/watches from hands and wrists;
- Consider having limited access to the laser area before starting;
    - Post signs, lock doors, erect barriers
- Alignment may be easier and safer with two qualified operators;
- Locate the proper safety goggles for the wavelength(s) of the laser(s);
- If the power output of the laser can be adjusted, set it to the lowest
    - Otherwise, install an attenuator directly in front of the output
    - A coaxial low power (visible) laser may fit into the optical layout
- Remove clutter from in and around the alignment area;
- Have everything you need on hand before beginning;
    - Fluorescing cards, screens, tools, etc.
- Check to see that all optics and translators are secure.

During Alignment:

- Wear the specified safety goggles;
- Never look directly into the beam, no matter what power;
    - A mirror or reflective surface can direct the beam inadvertently into someone's eye.
- Observe the beam indirectly using a card, screen, paper, fluorescent material, etc. (many items fluoresce at wavelengths which the laser goggles will transmit);
    - Class 4 lasers may ignite certain alignment aids
    - Class 3B lasers may also ignite certain materials when focused
    - Skin (hands, arms, etc.) should not be placed into the beam
- UV lasers present a "sunburn" hazard from scattered light;
    - Cover exposed skin.
    - **Wear specified safety goggles, even low power scattered UV light will burn the eyes!**
- With visible lasers, when the power is attenuated to below a Class 3B, safety glasses may be removed to view scattered light directly.

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BIOLOGY ALIGNMENT PRACTICES

Laser Alignment Fundamentals
-Class IIIb and IV Lasers-

Prealignment Procedures:

-Remove all jewelry/watches from hands and wrists
-Consider having limited access to the laser area before starting
*Post signs, lock doors, erect barriers…
-Alignment may be easier and safer with two qualified operators
-Locate the proper safety goggles for the wavelength(s) of the laser(s)
-If the power output of the laser can be adjusted, set it to the lowest
*Otherwise, install an attenuator directly in front of the output
*A coaxial low power (visible) laser may fit into the optical layout
-Remove clutter from in and around the alignment area
-Have everything you need on hand before beginning
*Fluorescing cards, screens, tools, etc.
-Check to see that all optics and translators are secure

During Alignment:

-Wear the specified safety goggles.
-Never look directly into the beam, no matter what power!
*A mirror or reflective surface can direct the beam inadvertently into someone's eye.
-Observe the beam indirectly using a card, screen, paper, fluorescent material, etc. (many items fluoresce at wavelengths which the laser goggles will transmit).
*Class IV lasers may ignite certain alignment aids!
*Class IIIb lasers may also ignite certain materials when focused.
*Skin (hands, arms, etc.) should not be placed into the beam.
-UV lasers present a "sunburn" hazard from scattered light.
*Cover exposed skin.
*Wear specified safety goggles, even low power scattered UV light will burn the eyes!
-With visible lasers, when the power is attenuated to below a Class IIIb, safety glasses may be removed to view scattered light directly.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Collider Accelerator Department (CAD) EEMC Laser Alignment

Effective Date:**Jan 23, 2015**

Collider-Accelerator Department (CAD) EEMC Laser Alignment is provided as a Word file.

Collider-Accelerator Department (CAD) EEMC Laser Alignment

Appendix 2: Procedure checklist

for alignment and maintenance of the EEMC Laser

(Only authorized and properly trained laser operators[*] listed in the SBMS Laser Controlled Area SOP may perform these steps. The lid of the primary box may be open.)

- Sign out the laser power supply key from the cabinet in the STAR trailer.
- Check that the removable access ladder is in place and available.
- Inspect primary, 1st-, and 2nd-level splitter boxes to ensure that no interconnecting fibers have been disconnected or removed.
- Verify the integrity of the enclosure curtain.
- Ensure that only authorized operator are within the curtained enclosure.
- Verify that operation of the primary box lid interlock: follow procedures and complete appropriate section of the "Laser Interlock Checklist."
- Set up laser warning sign at top of ladder and lighted sign at the access point.

[*] These individuals are listed in the EEMC Laser SBMS SOP as "Qualified Laser Operators"

- Check that the infra-red beam sensor is installed, and verify its operation: follow procedures and complete the “Laser Interlock Checklist.”
- Check that all operators inside laser enclosure are wearing authorized eye protection.
- Turn on AC power, use key to enable power supply.
- Use local control to energize laser to needed intensity

Additional safety steps for all lid-open operations

- Enable Infra-Red Interlock Mode.
- Ensure there are no mirrors or sharply reflective surfaces anywhere inside the primary box, other than those rigidly attached to the optical bench.
- Ensure that any temporary beam stops to be employed are diffusely reflective or absorptive.
- Set and keep the laser output intensity as low as possible during all alignment procedures.
- Do not leave the curtained area at any time while the lid is open.
- Disable Infra-Red Interlock Mode upon completion of alignment and maintenance operation.

Operator’s name (print): _____ Date: _____

Signature: _____

Appendix 3:

Procedure checklist to verify the operation of the EEMC Laser Interlock System

(These procedures may be performed only by authorized and properly trained laser operators.[*]
The lid of the primary box will be open during some steps.)

- Sign out the laser power supply key from the cabinet in the STAR trailer.
- Check that the removable access ladder is in place and available.
- Close the manual shutter on the laser head.
- Close the lid to the primary laser box.
- Turn on AC power, use key to enable the power supply.
- Set flashlamp voltage to zero.
- Put on authorized eye protection.
- Close the manual shutter on the laser head.

<u>Testing the primary box interlock:</u>

- Disable Infra-Red Interlock Mode.
- Close the lid to the primary laser box.

[*] These individuals are listed in the EEMC Laser SBMS SOP as "Qualified Laser Operators"

- Push the “stand-by” button; verify that laser is ready to fire (stand-by light remains on after 7-second warning beep).
- Open the box lid; verify that laser control reverts to “stop” mode.
- Verify that laser cannot be returned to “stand-by” mode with lid open.
- Close box lid; verify that laser can now be returned to “stand-by” mode.

<u>Testing the infra-red beam sensor interlock:</u>

- Enable Infra-Red Interlock Mode.
- Check that sensor system is installed and receiving AC power.
- Remove any interruptions to the IR beam (red light should go off).
- Push the “stand-by” button; verify that laser is ready to fire (stand-by light remains on after 7-second warning beep).
- Interrupt the IR beam; verify that laser control reverts to “stop” mode.
- Remove interruption; verify that laser can now be returned to “stand-by” mode.
- Disable Infra-Red Interlock Mode.

Operator’s name (print): _____ Date: _____

Signature: _____

[*] These individuals are listed in the EEMC Laser SBMS SOP as “Qualified Laser Operators”

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Engineered and Administrative Control Matrix

Effective Date:**Jan 23, 2015**

The table summarizes the hazard controls described by ANSI Z136.1-2007. The applicable sections are referenced in parentheses. The engineering control measures recommended in the table may be replaced by alternatives that are approved by the Laser Safety Officer and provide equivalent protection.

Control Measures	**Classification**						
Engineering Controls	**1**	**1M**	**2**	**2M**	**3R**	**3B**	**4**
Protective housing requirements (4.3.1)	R	R	R	R	R	R	R
Without protective housing (4.3.1.1)	Laser Safety Officer establishes Alternate Controls.						
Interlocks on removable protective housing (4.3.2)	E	E	E	E	E	R	R
Service access panel (4.3.3)	E	E	E	E	E	R	R
Key control (4.3.4)	--	--	--	--	--	S	R
Viewing Windows Display Screens and Collecting Optics (4.3.5.1)	Ensure viewing is < MPE						
Collecting optics (4.3.5.2)							
Fully open beam path (4.3.6.1)	--	--	--	--	--	R NHZ	R NHZ
Limited open beam path (4.3.6.2)	--	--	--	--	--	R NHZ	R NHZ
Enclosed beam path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 are fulfilled.						

Remote interlock connector (4.3.7)	--	--	--	--	--	S	R
Beam stop or attenuator (4.3.8)	--	--	--	--	--	S	R
Activation warning systems (4.3.9.4)	--	--	--	--	--	S	R
Indoor laser controlled area (4.3.10)	--	*	--	*	--	R NHZ	R NHZ
Class 3B laser controlled area (4.3.10.1)	--	--	--	--	--	R	--
Class 4 laser controlled area (4.3.10.2)	--	--	--	--	--	--	R
Outdoor control measures (4.3.11)	R	* NHZ	R NHZ	* NHZ	R NHZ	R NHZ	R NHZ
Laser in navigable airspace (4.3.11.2)	R	* NHZ	R NHZ	* NHZ	R NHZ	R NHZ	R NHZ
Temporary laser controlled area (4.3.12)	E MPE	E MPE	E MPE	E MPE	E MPE	--	--
Controlled operation (4.3.13)	--	--	--	--	--	--	S
Equipment labels (4.3.14 and 4.7)	R	R	R	R	R	R	R
Laser Area warning signs and activation warnings (4.3.9)	--	--	--	--	S	R NHZ	R NHZ
Administrative & Procedural Controls	**1**	**1M**	**2**	**2M**	**3R**	**3B**	**4**
Standard Operating Procedures (4.4.1)	--	--	--	--	--	R (BNL)	R
Output emission limitations (4.4.2)	--	--	--	--	Laser Safety Officer		

					determination		
Education and training (4.4.3)	--	S	S	S	S	R	R
Authorized personnel (4.4.4)	--	*	--	*	--	R	R
Alignment/Procedures (4.4.5)	E	E	E	E	E	R	R
Protective equipment (4.6)	--	*	--	*	--	S	R
Spectator (4.4.6)	--	*	--	*	--	S	R
Service personnel (4.4.7)	E	E	E	E	E	R	R
Demonstration with general public (4.5.1)	--	*	R	*	R	R	R
Laser optical fiber systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	R	R
Laser robotic installations (4.5.3)	--	--	--	--	--	R NHZ	R NHZ
Protective Eyewear (4.6.2)	--	--	--	--	--	S	R
Window Protection (4.6.3)	--	--	--	--	--	R	R NHZ
Protective barriers and curtains (4.6.4)	--	--	--	--	--	S	S
Skin protection (4.6.6)	--	--	--	--	--	R	R NHZ
Other protective equipment (4.6.7)	Use may be required.						
Warning signs and labels (4.7) (design requirements)	--	--	S	S	S	R NHZ	R NHZ

Service and repairs (4.4.7)	Laser Safety Officer determination
Modification and laser systems (4.1.2)	Laser Safety Officer determination

Legend				
R	Required		**E**	Required if enclosed Class 3B or Class 4
S	Suggested		**MPE**	Required if MPE is exceeded
--	No requirement		**NHZ**	Nominal Hazard Zone analysis required
*	May apply with use of optical aids			

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Before using a printed copy, verify that it is the most current version by checking the *effective date*.

Subject Area: ***Laser Safety***

Examples of Standard Operating Procedures (SOPs) from Working Laboratories

Effective Date:**Jan 23, 2015**

The Laser Controlled Area (LCA) Standard Operating Procedure (SOP) must be written for the installation it covers. The exhibit Examples of Standard Operating Procedures (SOPs) from Working Laboratories is provided to illustrate the implementation of the LCA-SOP for several installations at BNL. These documents are for guidance only.

Femtosecond Laser System for Surface Chemical Dynamics

LEAF laser systems

Soft Matter Physics Group, Optical Microscopy System for Organic Thin Films

Management System: ***Worker Safety and Health***

BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description:	Femtosecond Laser System for Surface Chemical Dynamics
Location:	Building 555, Room 353

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:

Name: Nicholas Camillone *Signature:* *Date:*

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

Chris Weilandics
BNL LSO printed name *Signature* *Date*

Jack Preses
BNL Associate LSO printed name *Signature* *Date*

Diane Cabelli
Department ES&H Approval printed name *Signature* *Date*

Alexander Harris
Chemistry Dept. Chair printed name *Signature* *Date*

APPLICABLE LASER OPERATIONS
☒ Operation ☒ Maintenance ☒ Service ☐ Specific Operation ☐ Fiber Optics

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls.

LASER RADIATION HAZARDS

There are two tables in this section: (1) *Laser System Characteristics* and (2) *Laser System Ocular Hazard Limits*. These provide guidance for understanding the hazards present when working with the lasers and wavelengths specified and are intended to raise awareness of when beams are especially hazardous. The first table identifies and classifies the lasers in use in the laboratory and the second table provides a quantitative indication of the hazard levels associated with each laser and wavelength. The following definitions and concepts are important to understanding and applying the information contained in the tables.

1. MPE (Maximum Permissible Exposure) Limits: The maximum level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

2. Class 2 Lasers: Lasers emitting low-power visible radiation (400–700 nm) that is a potential eye hazard, but for which eye protection is normally afforded by the natural aversion response to bright light, including the blink reflex. When viewed directly, such lasers cannot cause ocular damage in less than 0.25 s. However, intentionally overriding the natural aversion response *can* result in harm to the eye. For CW lasers, the emission limit is 1 mW.

3. Class 3b Lasers: Direct viewing of Class 3b lasers is a hazard to the unaided eye. The viewing of diffuse reflections may be safe for a short period of time at large enough viewing distances. These factors determining exposure must be carefully considered, even for viewing of diffuse reflections. For CW lasers, the maximum emission limit is 0.5 W.

4. Class 4 Lasers: Class 4 lasers are *inherently unsafe*. In addition to the hazards of direct, intra-beam viewing, they are capable of producing hazardous diffuse reflections. In addition, they can also present a skin hazard, and may pose a fire and fume hazard when interacting with target material.

5. Diffuse Viewing Limit: The diffuse viewing limit is a threshold that is specified in units of energy per pulse (for a *single* laser shot) or in power (for a cw laser) that depends on the wavelength and pulse characteristics of the laser. Lasers capable of emission levels above this limit pose a hazard when viewed in diffuse reflection based on the ANSI definitions for diffuse viewing (600 seconds, 20 cm distance, perfect reflectivity, normal to the card).

In summary, it is important to understand that:

- ***Direct, intrabeam exposure* of the unaided eye to radiation from *all* lasers classified as Class 2 and greater is hazardous.**
- ***Diffuse reflections* from Class 3b beams *may be* hazardous.**
- ***Diffuse reflections* from Class 4 beams *are* hazardous.**

LASER SYSTEM CHARACTERISTICS					
Laser Type	Wavelengths	ANSI Class	Maximum Power or Energy/Pulse	Pulse Length	Repetition Rate
He-Ne	632 nm	2	1 mW	CW	NA
diode-pumped, doubled $Nd:YVO_4$	532 nm	4	5 W	CW	NA
Ti:Sapphire oscillator	710 – 980 nm	4	10 nJ/ pulse	> 50 fs, < 100 fs	80 MHz
doubled Nd:YLF	527 nm	4	10 mJ/ pulse	350 ns	1 kHz
Ti:Sapphire regenerative amplifier	710 – 980 nm	4	1 mJ/ pulse	> 90 fs, < 130 fs	1 kHz

Laser classifications were determined using ANSI Z136.1-2000 Tables 1 and 2, with wavelength correction factors from Table 6. Some examples are in Tables A1 and A2. MPEs are used for determining the OD of laser eyewear for accidental intrabeam viewing. MPEs were calculated using ANSI Z136.1-2000 Table 5a, with wavelength and multiple pulse corrections from Table 6 as necessary, and following the rules in section 8.2.3. To provide for worst-case scenarios, it was assumed that beams matched the maximum ocular diameter for each wavelength in table 8; according to the standard, smaller beams are treated using the maximum ocular aperture as well. Such calculations can be involved; if there is any doubt, please see the owner/operator and/or the LSO listed on the first page of this SOP for assistance.

LASER SYSTEM OCULAR HAZARD LIMITS				
Laser Type	Wavelength (nm)	Intrabeam MPE Limit	Diffuse MPE Limit	Diffuse Viewing Limit
He-Ne	632 nm	6.4×10^{-1} mJ/cm^2	10×10^{-3} J/cm^2	21 mW
diode-pumped, doubled Nd:YVO_4	532 nm	6.4×10^{-1} mJ/cm^2	10×10^{-3} J/cm^2	21 mW
Ti:Sapphire oscillator	710 – 980 nm	13.3×10^{-9} mJ/cm^2	4.8×10^{-9} mJ/cm^2	6 nJ/pulse
doubled Nd:YLF	527 nm	126×10^{-6} mJ/cm^2	18×10^{-6} mJ/cm^2	22.6 μJ/pulse
Ti:Sapphire regenerative amplifier	710 – 980 nm	1.57×10^{-6} mJ/cm^2	564×10^{-9} mJ/cm^2	709 nJ/pulse

Note: The health effects of long term exposure to ultrafast laser pulses may not be fully understood.

The MPEs listed above are per pulse, and are the lowest values from calculations for multiple pulses. For CW lasers, MPEs represent the total allowable exposure. For both pulsed and CW, the time periods for direct viewing/specular reflections are 0.25 seconds for 400-700 nm, and 10 sec outside this range; for diffuse reflections, the time period is 600 seconds. Where multiple pulse corrections have been made for variable repetition rate sources, they were based on the highest possible rate.

Diffuse viewing limits provide a measure of the maximum permissible energy/power for the viewing of specific beams on cards based on the ANSI definitions for diffuse viewing (600 seconds, 20 cm distance, perfect reflectivity, normal to the card). These calculations involve many factors, and it may not be safe to simply scale these factors for different conditions.

☒ **Cryogen Use**

Describe type, quantity, and use.

L-N_2 used in cryostat in vacuum system for cooling crystal target. Approximate usage during experimental runs – 100 L/month. The L-N_2 is not used in direct connection with any of the lasers.

☒ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

As described in the Experimental Safety Review for the laboratory, CO-7-3. These are not used in direct connection with any of the lasers with a single exception. Compressed N_2 can be used to purge the Ti:S oscillator and Ti:S amplifier enclosures.

☒ **Electrical Hazards**

Description *(Describe the power supply to the system).*

All lasers have commercial power supplies. Under normal operating conditions, these present no hazard. High currents and voltages are present inside these supplies, and capacitors may hold dangerous energy even when the supply is turned off. Strict adherence to protocols is required if maintenance is required on the laser power supplies. Please refer to the Maintenance Procedures detailed below.

☒ **Other Special Equipment**

Description *(Equipment used with the laser[s]).*

The laser system is interfaced with a stainless steel UHV / atmospheric pressure reaction chamber as described in the Experimental Safety Review for the laboratory (CO-7-3). The output of either the Ti:S oscillator or the Ti:S amplifier is directed at the surface of crystals mounted either on the same optical table that holds the lasers or within the UHV chamber. Light reflected from the crystal surface is either terminated by a beam stop or collected and directed into spectrum analyzers comprised of filters and/or a monochromator and photomultiplier detector. Optical analytical instruments are fixed on the same optical table that holds the lasers or on the table supporting the UHV / atmospheric pressure reaction chamber.

Laser System Configuration:

Describe the system controls *(keys, switch panels, computer controls),* beam path, and optics *(provide a functional/block diagram for complicated beam paths)*.

Keys & Controls: The power supplies for the pump lasers (Nd:YVO_4 and Nd:YLF) are enabled by keyed power switches. Both also have remote electronic control boxes. Mode-locking of the Ti:S oscillator can be controlled by a Spectra Physics Model 3955 electronics module. A synchronization and delay generator (SDG) controls the emission of amplified light from the Ti:S regenerative amplifier.

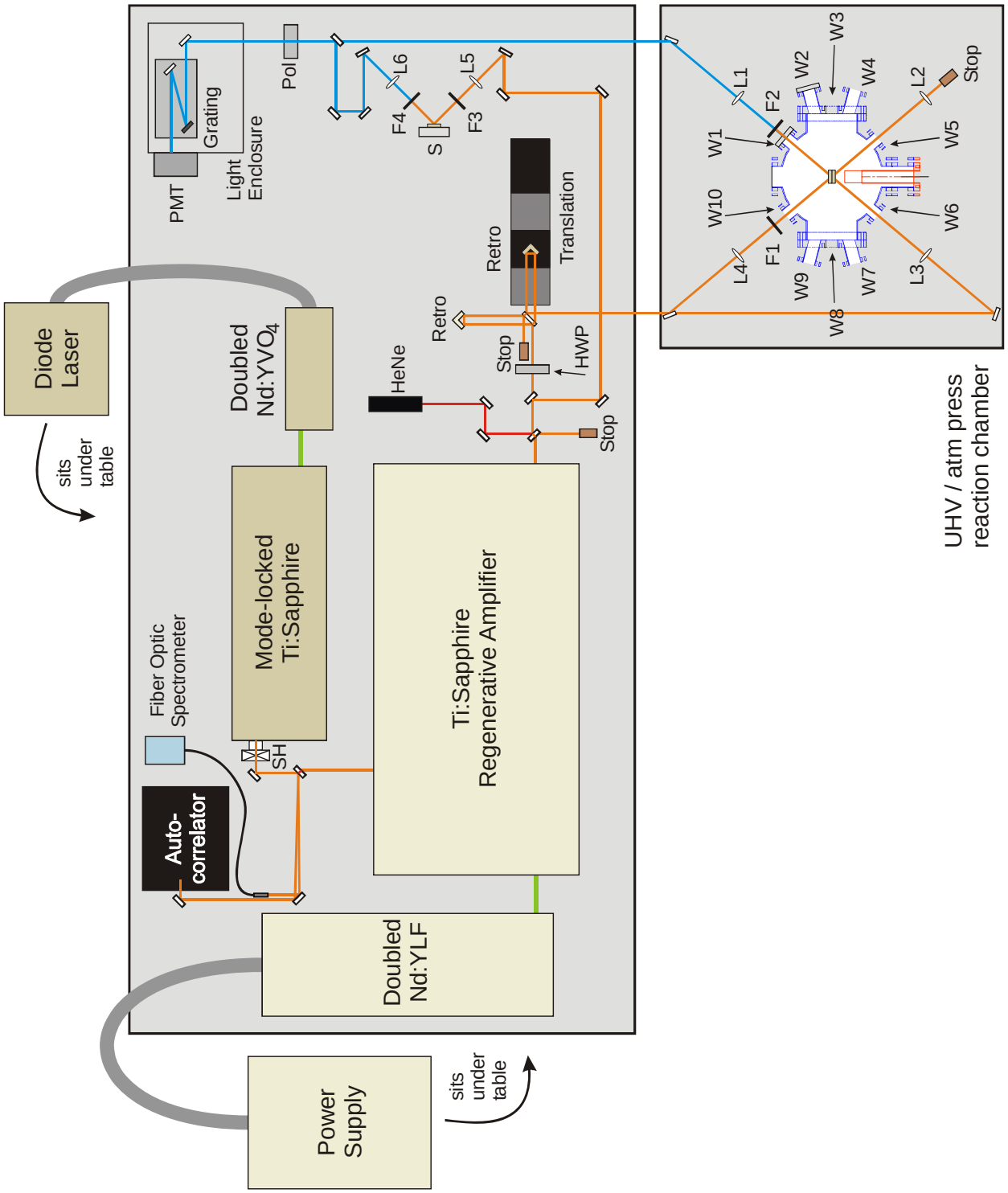
Beam Path: All lasers are operated on a fixed optical table with beams confined to the space above the table top. The single exception is when a beam is directed onto the experimental surface inside the reaction chamber described above and in the Experimental Safety Review for the laboratory. Beams reflected from the experimental surface are terminated by a beam stop or collected and redirected to the optical table for analysis. Propagation of the beam between the table and chamber is restricted to beam heights below 48 inches above the floor level.

The (~ 15 cm long) path of the pump beams between the Nd:YVO_4 and the Ti:S oscillator and between the Nd:YLF and the Ti:S regenerative amplifier are completely enclosed under normal operating conditions.

An experimental block diagram is provided below. *This diagram illustrates one of several possible configurations.* The locations of the Nd:YVO_4, Nd:YLF, Ti:S oscillator, Ti:S amplifier and UHV chamber are fixed. However, the detailed arrangements of the mirrors and diagnostics may vary depending upon the type of experiment being conducted.

Note that the UHV chamber has a total of 10 windows which may serve as entrance or exit ports. Any changes in the laser beam path must account for all possible reflections from the windows and the crystal and crystal holder at the center of the chamber, as well as direct and indirect propagation of light through the chamber. All beams are terminated by power-appropriate beam stops or in diagnostic equipment.

The experimental block diagram can be found on the page following.


Diode Laser
sits under table
Doubled Nd:YVO4
Mode-locked Ti:Sapphire
Fiber Optic Spectrometer
Auto-correlator
SH
Doubled Nd:YLF
Power Supply
sits under table
Ti:Sapphire Regenerative Amplifier
HeNe
Retro
Stop
HWP
Stop
Retro
Translation
PMT
Grating
Light Enclosure
Pol
L6
L5
F4
F3
S
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
L1
L2
L3
L4
F1
F2
Stop
UHV / atm press reaction chamber

DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures
☒ Beam Stop or Attenuator
☒ Activation Warning System
☐ Ventilation
☒ Protective Housing Interlocks
☒ Key Controls
☒ Other Interlocks
☒ Emission Delay
☐ Other

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review, a copy of the design review documentation and written testing protocol must be on file. Completed interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

Beam enclosures: During normal operation, lasers are only operated with the covers in place, with laser output only at the labeled apertures. The Nd:YVO_4 and Nd:YLF pump beams are fully enclosed in transit from the pump laser heads to the Ti:S oscillator or Ti:S amplifier. Alignment procedures requiring removal of enclosures are discussed below in the Administrative Controls section.

Actuated Beam Stops / Shutters: The Nd:YVO_4 and Nd:YLF lasers are outfitted by the manufacturer with intracavity shutters. The Ti:S oscillator is equipped with a solenoid-actuated external beam stop/shutter that is activated by the LCA door interlock system. When the interlock is tripped by emergency or unauthorized entry to the laboratory the beam stop blocks the output of the Ti:S oscillator. In addition, the beam stop can be closed by manually de-energizing the solenoid. The beam stop has a “normally closed” or “fail safe” design; i.e. when there is no power provided to it, the shutter is forced closed.

Static Beam Stops: Homebuilt beam stops are used to terminate all Class 3 and Class 4 beams not otherwise terminated by a detector or power meter.

Protective Housing Interlocks: All lasers are fitted by the manufacturer with protective housing interlocks as described in their corresponding manuals. The Ti:S oscillator, Ti:S regenerative amplifier and Nd:YLF laser have manufacturer-installed mechanical cover interlocks that close beam-entrance-port

or intracavity shutters when the enclosure covers are removed. These interlocks may only be defeated for the purposes of alignment within the enclosure as stipulated in the manuals provided by the manufacturer. The 532 nm pump laser has no cover interlocks as it contains no user-serviceable parts; removal of the protective housing requires the use of tools and is not to be performed by anyone other than those trained by the manufacturer (Spectra-Physics).

Activation Warning System: The Nd:YVO_4 and Nd:YLF lasers are outfitted by the manufacturer with illuminated activation indicators. In addition, the LCA door interlock system is equipped with a flashing LASER ON sign, as well as red and green indicator lights located both inside and outside the LCA near the door pushbuttons. These are illuminated when the interlock system is enabled.

Key Controls: The Nd:YVO_4 and Nd:YLF lasers are outfitted by the manufacturer with key controls. Both the Ti:S oscillator, Ti:S regenerative amplifier are passive devices dependant on pump beams and are not keyed.

Emission Delays: Once switched on, the Nd:YVO_4 laser will emit laser radiation only after an emission delay set by the manufacturer. The power button must be depressed once to initiate a temperature stabilization sequence and then depressed a second time for several seconds in order for the laser to initiate emission. During the latter process, the LASER EMISSION light flashes and, when emission begins, remains on to indicate that laser radiation is available if the shutter is open. The Nd:YLF laser requires enabling of the lamp for lasing to become possible. After a short delay, the LAMP ON indicator light illuminates. Pulsed radiation is emitted only after the Q-switch is activated and the internal shutter opened.

Other Interlock: the Laser Controlled Area (LCA) Door Interlock System. All Class 4 lasers are connected to the LCA door interlock system. Emergency or unauthorized entry to the laboratory will prevent laser radiation from leaving the emission ports of all Class 4 lasers in the manner described in the following.

Nd:YVO_4: Laser power supply is connected directly to the LCA interlock. Tripping of the interlock shuts down the power supply to the diodes.

Nd:YLF: Laser power supply is connected directly to the LCA interlock. Tripping of the interlock shuts down the power supply to the flash lamp.

Ti:S oscillator: Laser is equipped with an external solenoid-actuated beam stop. Tripping of the interlock closes the beam stop.

Ti:S amplifier: Emission from the amplifier is dependent upon input from the Nd:YLF and the Ti:S oscillator. Tripping of the interlock disables amplifier emission by shutting down the outputs from Nd:YLF and the Ti:S oscillator.

The LCA door interlock system employs magnetic sensor switches mounted on both doorways of the laboratory to detect entry to the LCA. Controlled access is implemented with pushbutton bypasses at the doors, which allows ~ 25 seconds for *authorized users* to enter or leave the LCA without shutting down the lasers. If the doors are opened without bypass, or held open longer than ~ 25 seconds, emission from all lasers is terminated.

As stipulated in the Administrative Controls Section, during normal operation, the output of the diode pumped-Nd:YVO_4 laser is entirely enclosed. Only under this condition may the relay controlling the power to the diodes be bypassed, and the solenoid-actuated beam stop will guarantee that no laser radiation is emitted into the room if the doors are opened without bypass.

The interlock system is tested every six months, and when a configuration change requires moving interlock cabling, by following a checklist protocol, exercising all components of the interlock system. The interlock circuit design follows the Chemistry Department standard for laser controlled areas, and is attached below. Documentation and inspection records are maintained in the laboratory.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☒ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOPs) are required for laser system operation, maintenance (including alignment), and servicing. The SOPs need only contain the information necessary to perform these tasks and identify appropriate control measures including postings and personal protective equipment. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Administrative Controls Description:

General:

1. Lasers listed in this SOP are operated only in room 353 (of building 555) which has been designated as a Laser Controlled Area.
2. All lasers have mandated labels provided by the manufacturer.
3. Appropriate warning signs and indicators are posted at each entrance. A flashing LASER ON warning light is mounted outside the main (front) entrance. Red and green indicator lights are located near the door pushbuttons both inside and outside the LCA at both the main (front) and service chase (back) entrance. The lights are illuminated whenever the interlock system is activated.
4. *The interlock needs to be activated in order for accessible laser light to be emitted into the LCA.* The laser interlock is wired such that accessible laser light cannot be emitted from any of the Class 4 laser sources unless the interlock system has been activated. Interlock and other hardware shall not be modified so as to defeat this purpose.

Operation SOP:

1. Only *authorized users listed in this document* are permitted to operate lasers in this laboratory.
2. Operation does *not* include gross alignment. Gross alignment may be performed only by those specifically trained and approved by the laser owner/operator. Gross alignment is defined below in paragraph 1 of the Alignment SOP.
3. Users must use good sense in avoiding actions that place themselves or coworkers at risk of laser-related injuries. If at any time a user is unsure of the correct procedure to follow, the user should STOP and seek the advice of the laser owner/operator.
4. Within the Nominal Hazard Zone (NHZ, see point 6 below), eyewear must be worn at all times. Remember that Class 4 laser beams can cause ocular damage even when viewed in diffuse reflection.
5. To reduce accidental reflections, watches, rings, dangling badges, necklaces, and reflective jewelry must be taken off before laser operations begin. Use of non-reflective tools should be considered. All unnecessary equipment, tools and combustible material (if fire is a possibility) are to be removed from the laser table surfaces to minimize the possibility of stray reflections and non-beam accidents.
6. Except during certain gross alignment procedures, all primary and specular beams, and diffuse reflections from Class 4 laser beams must be contained on the laser tables using non-combustible diffusely reflecting or absorbing laser beam stops that do not create hazardous vapors. Beams are diverted off tables (at heights below 48 inches above the floor) only to be directed into the UHV /

atmospheric pressure reaction chamber, and in such case the reflections are directed back to the laser table or terminated by a beam stop. Physical protection must be provided from vertical beams or any other situation where unexpected exposure might occur. Under these conditions, the Nominal Hazard Zone (NHZ) is confined to the space above the laser tables and the UHV reaction system. Eye protection as specified below (in the PPE section) is required for work within the NHZ.

7. All optics must be solidly attached to laser tables so that accidental “bumps” cannot send beams in unknown directions. Likewise, hand held optical devices including mirrors and filters are never to be inserted into the beam.
8. Lasers should be operated at the minimum intensity consistent with experimental requirements.
9. During normal operation, the 532 nm and 527 nm beams must remain entirely enclosed, the covers must remain on all laser enclosures, and the interlocked shutter must be in place at the output of the Ti:S oscillator. If and only if these conditions are met, the interlock relay controlling the pump laser diodes for the 532 nm laser may be bypassed (deactivated) using the bypass switch.
10. Users must know and follow the routine operation instructions for all lasers as described in the manuals provided by the laser vendors.

Alignment SOP:

1. The type of alignment addressed by the procedures in this section is defined herein as gross alignment, namely any operation involving significant deviation of the beam from its previously established path. This specifically includes:
   (1) any insertion or removal of optical components (including mirrors, lenses, and other devices but not including beam stops or power meters) into or from the previously established beam path,
   (2) any alteration of the beam path that may cause the beam to deviate sufficiently so as to miss an optic or target in the previously established beam path, and
   (3) any work within the laser enclosures involving removal of the enclosure covers.
2. Gross alignment may be performed only by those specifically trained and approved by the laser owner/operator, as documented in the training qualifications table below.
3. During gross alignment procedures, only persons immediately involved in the procedure are to be in the laboratory. These individuals must have appropriate training and be listed in this document as authorized laser users.
4. Eyewear must be reviewed to ensure it provides adequate protection against the full intensity of light at all wavelengths present. Eyewear within the parameters and notes established on the accompanying eyewear table must be worn at all times except where detailed in this SOP.
5. There shall be no intentional intrabeam viewing with the eye.
6. Wherever possible, co-axial low power lasers (e.g., HeNe) should be used when practical for alignment of the primary beam.
7. Definite termination of the beam path must be in place before the beam is allowed to propagate.
8. Alignment procedures are always to be performed with the minimum practical laser power levels and repetition rates.
9. Following a new laser beam set-up or change in alignment, a survey of the unenclosed beam path will be conducted to verify that all unwanted beams and reflections have been properly terminated. An IR viewer shall be used to trace all NIR and IR reflections. Opaque barriers will be used to confine low intensity stray reflections and scattered light to the optical tables. Any unwanted primary or specular beams will be terminated in a beam stop that does not produce hazardous diffuse reflections.
10. Gross alignment of beams from Class 4 lasers into the UHV chamber, Ti:S laser enclosures or experiments on the optical table should be done with beams attenuated as far below Class 4 thresholds as possible, with eye protection adequate for the beam in use. Provided that the beams are attenuated below the diffuse viewing limit (see the Laser System Ocular Hazard table above), and any specular beams are fully controlled, the laser path may be visualized by placing a matte-finished hand-held white card or paper in the path and viewing the diffuse reflection with the laser eyewear *momentarily* removed. This shall be done only by personnel authorized for alignment procedures. It is

important to understand that even when viewed in diffuse reflection, ocular damage can result from momentary unprotected viewing of Class 4 or prolonged viewing of lower intensity laser radiation. In addition, specular or intra-beam viewing of lasers emitting radiation at Class 3b levels will likely cause ocular damage. At no time should any hand-held reflective instrument be placed in the beam.

11. Routine laser-specific alignment procedures may be simple or complex. In either case, specific procedures are outlined in the operation and alignment manuals supplied by the manufacturers, and they must be followed. If at any time an alignment-authorized user is unsure of the correct procedure to follow, the user should STOP and seek the advice of the laser owner/operator.
12. During alignment when any of the following conditions are true, the interlock relay controlling the 532 nm pump laser diodes MUST be active (i.e., interlocked via the interlock system to the laboratory entrance sensors such that unauthorized entry causes the laser power supply to the diodes to shut down):
    (1) the 532 nm pump laser beam enclosure is removed,
    (2) the cover of the Ti:S oscillator enclosure is removed, OR
    (3) the Ti:S oscillator output shutter is in any way disabled.
13. Alignment of the visible (green) pump beams into the either of the Ti:S enclosures is particularly hazardous due to the presence of Class 4 radiation both in the green and the NIR. Alignments must be performed in accordance with the laser user manuals. Full protection against beams at all wavelengths involved must be worn, and an IR viewer shall be used to visualize the NIR beams.
14. Normal laser hazard controls shall be restored when the alignment is completed. Enclosures, covers, beam blocks and barriers must be replaced, and affected interlocks checked for proper operation.

Other Maintenance SOP

1. Relatively little routine maintenance is required for the above described laser system. Procedures such as optics cleaning and/or replacements are to be conducted in strict accordance with the methods described in the user's manuals provided by the manufacturers, and only by individuals with appropriate training who are listed in this document.
2. The Nd:YVO_4 laser requires no routine alignment or maintenance. There is no reason to remove the outer cover as there are no serviceable parts inside the laser head. Only those diagnostics detailed in the Troubleshooting Guide of the user's manual may be performed. Other procedures must be performed by a Spectra-Physics technician or under the strict guidance of a Spectra-Physics service representative.
3. The Nd:YLF laser periodically requires flashlamp replacement, cavity alignment and replacement of the deionization filter. These are to be performed in accordance with the procedures detailed in the manual supplied by the laser manufacturer (Spectra-Physics) and this SOP.
4. Routine maintenance for the Ti:S oscillator includes cleaning and realigning of optics, which requires removal of the laser cover. This may be done only in strict accordance with the procedures outlined in the user's manual and this SOP.
5. Routine maintenance for the Ti:S regenerative amplifier includes cleaning and realigning of optics, which requires removal of the laser cover. This may be done only in strict accordance with the procedures outlined in the user's manual and this SOP.
6. Non-routine maintenance and troubleshooting is a serious matter, as injury or damage to equipment could result from actions taken in unfamiliar circumstances. Non-routine maintenance includes any repairs of the lasers not outlined in the user's manuals. When an uncharacterized fault condition exists, some actions that would be safe under ordinary conditions may have unsuspected hazards. Diagnostic work on optics or electronics will thus only be undertaken strictly following specific instructions in the laser manual, or in consultation with the manufacturer's service engineering staff. In no case is "working hot" on power supplies permitted. When there is any uncertainty about the safety of a diagnostic procedure, do not attempt it and seek additional expert guidance. The laser manufacturer's field service engineers may be required to perform specialized maintenance tasks for which lab employees lack specific expertise and training.

CONFIGURATION CONTROL

A checklist must be developed for the purpose of verifying the placement and/or status of components that are used to mitigate hazards by configuration control. Examples include any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Entries should also be included to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

Laser Enclosure Covers:

must be in place during normal operation. They may be removed temporarily for alignment.

☐ **Nd:YLF**

☐ **Ti:S oscillator** _____ *Important!: When this beam enclosure is removed, the interlock relay controlling the Nd:YVO_4 laser must be enabled.*

☐ **Ti:S amplifier**

Beam Enclosures:

must be in place during normal operation. They may be removed temporarily for alignment.

☐ **Nd:YVO_4 output**_____ *Important!: When this beam enclosure is removed, the interlock relay controlling the Nd:YVO_4 laser must be enabled.*

☐ **Nd:YLF output**

Actuated Beam Shutter:

must be in place and enabled during normal operation.

☐ **Ti:S oscillator output**_____ *Important!: When this shutter is removed or disabled, the interlock relay controlling the Nd:YVO_4 laser must be active.*

Beam stops and optical components on both the main optical bench (table) and the UHV chamber bench are subject to frequent changes in configuration on a daily basis. *The user should never assume that all beams are confined within the NHZ described in the SOP*; rather the beam path and absence of stray reflections must be confirmed each day upon initial start up as well as subsequent to any changes in the configuration. These confirmations shall be performed prior to and after allowing the beam to propagate through the full optical train by:

(1) referring to the laboratory notebook to check for recent modifications to the optical train,
(2) surveying the expected beam path to confirm that it is clear of obstructions,
(3) surveying the expected beam path to confirm that optics are secured to the optical bench and in good condition,
(4) using beam stops to sequence beam propagation through subsections of the optical train, AND
(5) checking for stray reflections after the laser is first allowed to propagate through the optical train.

PERSONAL PROTECTIVE EQUIPMENT

☐ Skin Protection ☒ Eye Wear

Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE) describe the nature of the hazard and the steps that will be taken to protect against the hazard.

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

Preventative Precautions:
During normal operation, for deep red or invisible IR (~ 700 nm or greater) beams, eye protection against the full beam must be worn at all times within the NHZ defined in the Operation SOP above. Once the IR beam path has been established and all beams are fully enclosed or the absence of stray reflections has been carefully confirmed by means of an IR viewer, standard polycarbonate safety glasses may be worn *outside* the NHZ provided *all* personnel remain *outside* the NHZ. Under these conditions, *no adjustments to any of the beams are to be made*.

For the 532 nm and 527 nm beams, eye protection against the full beam must be worn during gross beam alignment. During alignment procedures, beam position may be checked and the laser path may be visualized by placing a matte-finished hand-held white card or paper in the path and viewing the diffuse reflection *momentarily* with the unprotected eye provided that the beams are attenuated as far below the diffuse viewing threshold (see chart) as practicable, and any specular beams are fully controlled. During normal operation the 532 nm and 527 nm beams are to remain *fully enclosed* and eye protection against this wavelength is not required.

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

EYE WEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
He-Ne	632 nm	NA	NA	NA	NA
diode-pumped, doubled Nd:YVO_4	532 nm	3.7 (0.25 sec.)	2.4	3.1 m	1, 3
Ti:Sapphire oscillator	710 – 980 nm	3.3 (10 sec.)	0.2	0.26 m	2, 3, 4
doubled Nd:YLF	527 nm	5.3 (0.25 sec.)	2.7	4.2 m	3
Ti:Sapphire regenerative amplifier	710 – 980 nm	6.2 (10 sec.)	3.15	7.5 m	3, 4‡

* Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

EYE WEAR SPECIFICATIONS					
Laser System Eyewear Identification				Wavelengths (nm)	Optical Density
#	Model	Type	Color		
1	Cascade Laser Corp, Ar Ion	Polycarbonate wrap	Orange	190–375	5+
				375–532	4+
				10600	6+
2	Glendale Laser-Gard, NdGa:YAG	Polycarbonate wrap	Green	190–420	9+
				770–810	5+
				810–1100	7+
				1064	10+
				5000–11000	7+
3	Trinity, Glass Filter 1126	Spectacle	Brown	190-540	6+
				632	2+
				650-690	3+
				690-710	6+
				710-1200	8+
				10,600	5+
4	Trinity, Polycarbonate Filter 1205	Spectacle	Amber-Pink-Brown	190-375	5+
				730-855	4+
				755-840	7+
				10,600	6+

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL World Wide Web based training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

All laser safety training must be repeated every two years.

SOP SIGNATURES

The signatures of the personnel listed in the following table indicate that these personnel have read and understood the contents of this SOP and agree to adhere to the guidelines detailed in therein. The signature of the Owner/Operator indicates that the Owner/Operator has reviewed this SOP with the User to ensure that its contents have been clearly communicated and understood. Only persons who have signed below and been authorized by the Owner/Operator may operate the lasers covered by this SOP. SOP Signatures are necessary but do not document complete authorization. Other required training elements and documentation are described immediately above in the “Laser Safety Training” section.

User Printed Name	Signature	Date	Owner/Operator Signature
Owner: Nicholas Camillone	———		
Paul Szymanski			

BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description:	LEAF laser systems
Location:	Building 555, LEAF Rooms 21,22, and 23

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:

Name:	Andrew Cook	*Signature:*	*Date:*
	James Wishart	*Signature:*	*Date:*

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

Christopher Weilandics
BNL LSO *Signature* *Date*

Diane Cabelli
Department ES&H Approval *Signature* *Date*

Alexander Harris
Chemistry Dept. Chair *Signature* *Date*

Jack Preses
BNL ALSO & Chemistry Dept. Laser Safety Coordinator *Signature* *Date*

APPLICABLE LASER OPERATIONS
☒ Operation ☒ Maintenance ☒ Service ☐ Specific Operation ☒ Fiber Optics
Fiber Optics carry light to detectors in a few places.

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls.

LASER RADIATION HAZARDS

There are two tables in this section: (1) *Laser System Characteristics* and (2) *Laser System Ocular Hazards*. These provide guidance for understanding the hazards present when working with the lasers and wavelengths specified and are intended to raise awareness of when beams are especially hazardous. The first table identifies and classifies the lasers in use in the laboratory and the second table provides a quantitative indication of the hazard levels associated with each laser and wavelength. The following definitions and concepts are important to understanding and applying the information contained in the tables.

1. MPE (Maximum Permissible Exposure) Limits: The maximum level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

2. Class 2 Lasers: Lasers emitting low-power visible radiation (400–700 nm) that is a potential eye hazard, but for which eye protection is normally afforded by the natural aversion response to bright light, including the blink reflex. When viewed directly, such lasers cannot cause ocular damage in less than 0.25 s. However, intentionally overriding the natural aversion response *can* result in harm to the eye. For CW lasers, the emission limit is 1 mW.

3. Class 3b Lasers: Direct viewing of Class 3b lasers is a hazard to the unaided eye. The viewing of diffuse reflections may be safe for a short period of time at large enough viewing distances. These factors determining exposure must be carefully considered, even for viewing of diffuse reflections. For CW lasers, the maximum emission limit is 0.5 W.

4. Class 4 Lasers: Viewing direct beams or diffuse reflections from Class 4 lasers is *inherently unsafe*. In addition, lasers in this class can also present a skin hazard, and may pose a fire and fume hazard when interacting with target material.

5. Diffuse Viewing Limit: The diffuse viewing limit is a threshold that is specified in units of energy per pulse (for a *single* laser shot) or in power (for a cw laser) that depends on the wavelength and pulse characteristics of the laser. Lasers capable of emission levels above this limit pose a hazard when viewed in diffuse reflection based on the ANSI definitions for diffuse viewing (600 seconds, 20 cm distance, perfect reflectivity, normal to the card).

In summary, it is important to understand that:
- ***Direct, intrabeam exposure* of the unaided eye to radiation from *all* lasers classified as Class 2 and greater is hazardous.**
- ***Diffuse reflections* from Class 3b beams *may be* hazardous.**
- ***Diffuse reflections* from Class 4 beams *are* hazardous.**

LASER SYSTEM CHARACTERISTICS

Laser Type *(Argon, CO2, etc)*	Wavelength (nm)	ANSI Class	Maximum Power or Energy/Pulse	Pulse Length	Repetition Rate
1. Spectra Physics Millennia Vi diode-pumped Nd:YVO4	532 nm	4	5.5 W	CW	CW
2. Spectra Physics Tsunami Ti:Sapphire Oscillator	798 nm	4	800 mW	100 fs	81.6 MHz
3. Quanta-Ray GCR 170-10 Nd:YAG (seeded)	1064 nm‡ 532 nm 266 nm	4 4 4	850 mJ 450 mJ 90 mJ	8-12 ns 6-11 ns 4-9 ns	10 Hz 10 Hz 10 Hz
4. Quanta-Ray Pro-290-30 Nd:YAG (fixed at 10Hz)	1064 nm‡ 532 nm	4 4	1600 mJ 800 mJ	8-12 ns 6-11 ns	10 Hz 10 Hz
5. Positive Light TSA-10 Ti:Sapphire Amplifier	800 nm 800 nm		6 mJ 10 mJ	1-3 ps 200 ps	10 Hz 10 Hz
6. Homebuilt pulse compressor	800 nm 800 nm		3 mJ 1 mJ	100 fs 100 fs	10 Hz 10 Hz
7. Homebuilt tripler	400 nm 266 nm		1.5 mJ 0.5 mJ	100 fs 100 fs	10 Hz 10 Hz
8. Quantronix Topas 4/800 Optical Parametric Amplifier	200-400 nm 400-700 nm 700-1050 nm 1.05-1.20 um 1.2-1.4 um 1.4-2.6 um		35 uJ 190 uJ 100 uJ 150 uJ 300 uJ 300 uJ	100 fs	10 Hz
9. Power Technology Inc. PMT70(658-80B)G2	658 658	3b	70.9 mW 7.09 uJ	CW 100 uS	CW 60 Hz
10. Power Technology Inc. PMT120(808-150B)G2	808 808	3b	120.1 mW 12.01 uJ	CW 100 uS	CW 60 Hz
11. Power Technology Inc. PMT(LD1415)G2	639 639	3b	35 mW 3.5 uJ	CW 100 uS	CW 60 Hz
12. Power Technology Inc. PMT(LD1438)G2	685 685	3b	60 mW 6 uJ	CW 100 uS	CW 60 Hz
13. Power Technology Inc. PMT90(980-100B)G2	980 980	3b	100 mW 10 uJ	CW 100 uS	CW 60 Hz
14. Power Technology Inc. PMT32(1300-50B)G2	1300 1300	3b	50 mW 5 uJ	CW 100 uS	CW 60 Hz
15. Power Technology Inc. PMT27(1550-40B)G2	1550 1550	3b	40 mW 4 uJ	CW 100 uS	CW 60 Hz
16. Various HeNe and diode alignment lasers	632-690 nm	2, 3a	1-5 mW	CW	CW

17. Daylight Solutions Quantum Cascade Laser Model 21052-MHF	5102-5294 nm	3R	< 0.1 W	CW	1.26×10^8 $\mu W/cm^2$
18. Daylight Solutions Quantum Cascade Laser Model 21049-MHF	4798-5010 nm	3R	< 0.1W	CW	1.26×10^8 $\mu W/cm^2$

‡ 1064 nm outputs are normally terminated inside the laser cabinets, or at the exit in an external beam dump.

Laser System Ocular Hazard Limits

Laser Type *(Argon, CO2, etc)*	Wavelength (nm)	Intrabeam MPE Limit (mJ/cm^2)	Diffuse MPE Limit (mJ/cm^2)	Diffuse Viewing Limit (uJ/pulse)
1. Spectra Physics Millennia Vi diode-pumped Nd:YVO4	532 nm	0.64	10	21 **mW**
2. Spectra Physics Tsunami Ti:Sapphire Oscillator	798 nm	1.92×10^{-8}	7.00×10^{-9}	8.8 **nJ**
3. Quanta-Ray GCR 170-10 Nd:YAG	1064 nm‡ 532 nm 266 nm	1.58×10^{-3} 3.98×10^{-4} 3.00×10^{-2}	5.68×10^{-4} 5.68×10^{-5} 5.00×10^{-4}	714 71.4 628
4. Quanta-Ray Pro-290-30 Nd:YAG	1064 nm‡ 532 nm	1.58×10^{-3} 3.98×10^{-4}	5.68×10^{-4} 5.68×10^{-5}	714 71.4
5. Positive Light TSA-10 Ti:Sapphire Amplifier	800 nm 800 nm	7.52×10^{-6} 7.20×10^{-5}	2.70×10^{-6} 2.59×10^{-5}	3.4 32
6. Homebuilt pulse compressor	800 nm 800nm	7.52×10^{-6} 7.52×10^{-6}	2.70×10^{-6} 2.70×10^{-6}	3.4 3.4
7. Homebuilt tripler	400 nm 266 nm	1.19×10^{-5} 3.00×10^{-2}	1.70×10^{-6} 5.00×10^{-4}	2.1 628
8. Quantronix Topas 4/800 Optical Parametric Amplifier†	200-400 nm 400-700 nm 700-1050 nm 1.05-1.20 um 1.2-1.4 um 1.4-2.6 um	3.00×10^{-2} 1.19×10^{-5} 4.77×10^{-6} 4.74×10^{-5} 3.97×10^{-4} 1.00	5.00×10^{-4} 1.70×10^{-6} 1.71×10^{-6} 1.70×10^{-5} 1.36×10^{-4} 4.62×10^{-1}	628 2.1 2.1 21 171 580 **mJ**
9. Power Technology Inc. PMT70(658-80B)G2	658 658	0.64 9.15×10^{-4}	0.64 1.31×10^{-4}	 164
10. Power Technology Inc. PMT120(808-150B)G2	808 808	1.66 5.98×10^{-4}	1.64 2.15×10^{-4}	 270
11. Power Technology Inc. PMT(LD1415)G2	639 639	2.55 9.15E-04	1.00 1.31E-04	 164.21
12. Power Technology Inc. PMT(LD1438)G2	685 685	2.55 9.15E-04	1.00 1.31E-04	 164.21
13. Power Technology Inc. PMT90(980-100B)G2	980 980	3.68 1.32E-03	3.63 4.74E-04	 596.22
14. Power Technology Inc. PMT32(1300-50B)G2	1300 1300	40.5 1.45E-02	40.0 5.23E-03	 6568.51
15. Power Technology Inc. PMT27(1550-40B)G2	1550 1550	100 1.67	100 1.67	 2.1 J
17. Daylight Solutions Quantum Cascade Laser Model 21052-MHF	5102-5294 nm	0.1 W/cm^2	0.1 W/cm^2	1.26 × 108 μW

18. Daylight Solutions Quantum Cascade Laser Model 21049-MHF	4798-5010 nm	0.10.1 W/cm^2	0.1 W/cm^2	

† MPEs depend greatly on wavelength; MPE listed is the minimum for each range shown.
‡ 1064 nm outputs are normally terminated inside the laser cabinets, or at the exit in an external beam dump.

Please note: The MPEs listed above are per pulse, and are the lowest values from calculations for multiple pulses. For CW lasers, MPEs represent the total allowable exposure. For both pulsed and CW, the time periods for direct viewing/specular reflections are 0.25 seconds for 400-700 nm, and 10 sec outside this range; for diffuse reflections, the time period is 600 seconds. Where multiple pulse corrections have been made for variable repetition rate sources, they were based on the highest possible rate.

Diffuse viewing limits provide a measure of the maximum permissible energy/power for the viewing of specific beams on cards based on the ANSI definitions for diffuse viewing (600 seconds, 20 cm distance, perfect reflectivity, normal to the card). These calculations involve many factors, and it may not be safe to simply scale these factors for different conditions.

☒ **Cryogen Use**

Describe type, quantity, and use.

Liquid nitrogen is used occasionally for the cooling of a CCD camera and samples.

☒ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

Compressed Nitrogen (~100psi max) from a generator in the chase is used as purge for laser cavities.
Small amounts (< 1 liter) of methanol and acetone used for cleaning optics.
Small quantities of samples (< 10 ml in cells, < 1000 ml in flow systems) may be present containing various solvents and solutes. The preparation and handling of samples is covered in ESR CO-4-9.

☒ **Electrical Hazards**

Description *(Describe the power supply to the system).*

All lasers in this facility have commercial enclosed power supplies, and under normal operating conditions present no hazard. High currents and voltages are present inside power supplies, and may remain hazardous even after the power is shut off due to the large capacitors present. Interiors of laser heads such as those of Nd:YAG lasers in the facility also present high voltage and current risks. Where deemed necessary by the manufacturers, particularly hazardous areas have warning labels. In no case is routine operation allowed with either power supply or laser head cabinets open. In some cases, such as optical alignment in laser heads as well as other maintenance tasks, it is necessary to operate lasers with cabinet interlocks defeated. In such cases, special attention must be given to the possibility of both electrical and optical hazards. In some cases, specific procedures exist and must be followed as described in the manufacturer's manuals. We have minimized risks further by installing several plastic covers in the Nd:YAG laser head to isolate high voltage and current risk areas from the user. This includes the flashlamp terminals as well as the Pockels' cell. These shall not be removed during alignment procedures.

The TSA-10 amplifier has high voltage drivers inside the non-interlocked case to power the 2 Pockels' cells in the regenerative amplifier section. The connections are covered by metal caps labeled with high voltage stickers. In no instance can these devices be energized without the protective caps in place. The 500 VDC power for the drivers is current limited (10mA). Care must be taken with the power cables to avoid cutting them or exposing the hot pins when it is required to disconnect them.

☒ **Other Special Equipment**

Description *(Equipment used with the laser[s]).*

Leaf accelerator and detection systems: described in the LEAF SAD, which was approved 1/97.
Hammamatsu Streak camera used for time resolved emission work. Photodiodes, photomultiplier tubes, and other light sources such as 75 Watt Xenon short-arc lamps (typically ozone free, but when needed possibly not – in which case venting of produced ozone will be done when necessary) are used in conjunction with lasers and depending on sample needs and experimental detection system. Note that many of these devices must be handled with care and in accordance with the manufacturer instructions as high voltages and/or currents and intense light sources are involved.

Laser System Configuration:

Describe the system controls *(keys, switch panels, computer controls),* beam path, and optics *(provide a functional/block diagram for complicated beam paths)*.

All primary lasers are located in the laser room of the LEAF facility. Beams used for generating electrons in the LEAF gun and for diagnostic probes are transported through tubes in the wall to the LEAF vault area. In the vault area, a laser probe beam (max 1 mJ, various colors) crosses from one table to another using a gravity shutter and tube (shutter is closed if safety tube removed). In another experiment, an excitation beam (max 6 mJ, various colors) travels from the small table in front of the laser room exit tube to the table at electron beam port B near the vault entrance. In this case, the beam passes across floor space near the electron beam pipe. When this beam is present, the area will be roped off with a plastic safety chain and a sign noting the hazard. Otherwise, all laser beams (thus the nominal hazard zone or NHZ) are confined to the tabletops under normal operating conditions.

All primary pump lasers (Nd:YAG and diode pumped Nd:YVO4) are enabled by key switches and power breakers on the power supplies, and are mostly activated by remote control units.

All primary class 4 pump laser beams are enclosed in beam tubes between laser enclosures in areas where it is possible to easily and inadvertently obstruct the beam. For normal operation these tubes must be kept in place due to the very high energy/pulse in these beams.

In general, no laser light is allowed to exit the LCA (laser room and vault). An exception is the small amount of light from the Ti:Sapphire oscillator is coupled into a fiber in the laser room. This fiber terminates in the control room outside the LCA into a detector used for experiment timing and triggering. Under no circumstances is this fiber (labeled with a warning) to be disconnected from the detector during operation.

Another exception is beams from the class 3b laser diode modules and 3R quantum cascade lasers when they are used as probe light for experiments. At such times, the modules are operated in the vault area, not the laser room. Laser diode modules are driven from a key switched control unit and external TTL trigger source. The external source will either allow CW operation, or more typically pulsed at either 60 Hz or single pulse. Since they are not interlocked, when these modules are in use a warning sign will be posted to notify those entering the area.Light is routed from these modules through samples, and then out of the vault through the hole in the wall normally used for arc-lamp probe light. In the control room, the laser light must be contained by barriers and properly terminated in such a way that inadvertent exposure to direct or scattered laser light is prevented. When not in use, they must be shuttered or switched off. The control room will be posted outside the entrance and in the vault door. Bystanders will not be permitted in the control room or vault during alignment.

DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

BNL SBMS Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☒ Beam Enclosures
☒ Beam Stop or Attenuator
☒ Activation Warning System
☐ Ventilation
☒ Protective Housing Interlocks
☒ Key Controls
☒ Other Interlocks
☒ Emission Delay
☐ Other

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review, a copy of the design review documentation and written testing protocol must be on file. Completed interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

All commercial lasers are outfitted by the manufacturer with the federally mandated labels, beam stops, audible or visual activation indicators, key controls, protective housing interlocks, remote interlock connectors, and emission delays.

Beam enclosures: During standard operation, lasers are only operated with the covers in place, with laser output only at the labeled apertures. Class 4 pump laser beams are enclosed in rigid tubes where they are accessible. Class 4 beams do not cross any floor space where someone could walk into the beam.

Interlock system: The LEAF facility has two Laser Controlled Areas (LCAs): the laser room itself, and the vault area where the accelerator is. All class 4 pump lasers and the 3b sources they pump are located in the laser room, and are connected to a door interlock system. Emergency or unauthorized entry to this area will shut down all of the class 4 and 3b lasers in the facility by shutting down the pump laser power supplies. Controlled access is implemented with a pushbutton at the doors, which allows ~20 seconds for authorized users to enter or leave the laser controlled area without shutting down the lasers. If someone enters or leaves the LCA without using the bypass, or a door is held open longer than ~20 seconds, all lasers immediately cease output. Laser beams are brought through tubes in the concrete wall separating the laser room from the vault. Before entering these tubes however, they are intercepted by mechanical

shutters that form the basis for the interlock system for the vault LCA. Similar to the laser room, the vault area is protected by entry interlocks, but which only serve to close the shutters instead of turning off the laser power supplies if tripped. The vault area uses electric-eye entry interlocks rather than door interlocks to satisfy radiation protection rules that state that no personnel can be in the vault area with the doors closed (and radiation interlocks potentially active).

The interlock system is tested every six months, and is part of the LEAF area total interlock system. This contains interlocks for not just the lasers, but also the accelerator radiation safety system. The interlock design has been qualified during an accelerator readiness review (ARR) as a “catastrophic” level system. It also follows the Chemistry department standard for laser control areas, and includes a flashing “laser on” sign for the laser room, and yellow lamp indicators for when the laser interlock in the vault area LCA is enabled. Documentation and inspection records are maintained in the file cabinet at LEAF, along with certification, design, and test procedures.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☒ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOPs) are required for laser system operation, maintenance (including alignment), and servicing. The SOPs need only contain the information necessary to perform these tasks and identify appropriate control measures including postings and personal protective equipment. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Administrative Controls Description:

General comments for all work in LEAF LCAs:

1. All lasers under this SOP are operated in the LCAs at LEAF described above. Appropriate warning signs are posted at each entrance. All lasers have mandated labels. Flashing warning signs, activated whenever the interlock system is live, are mounted outside the main laser room entrances. Yellow warning lights are lit at the doors to the vault when its interlock system is active.

2. Remember that Class 4 laser beams are dangerous to view even in diffuse reflection. Class 4 limits and MPEs for all wavelengths emitted by lasers covered by this SOP are listed in the section "Analyze the Laser System Hazards" above, and eyewear requirements are listed in the eyewear table below. Requirements for when/what eyewear is required are discussed below.

3. Before working within the laser nominal hazard zones at LEAF, users must remove personal objects that might intercept a beam accidentally during work. This is especially true for shiny BNL badges attached to ropes around your neck or even clipped to shirts, and things like rings and watches when making laser adjustments. Such objects make very good reflectors that could cause specularly reflected beams to leave the NHZ in an uncontrolled fashion, possibly injuring yourself or a co-worker.

4. Users must use good sense in avoiding actions that place themselves or co-workers at risk of laser-related injuries. Users must be aware of others in the LCA, especially those who enter the area while work is in progress.

5. If at any time a user is unsure of the correct procedure to follow, the user shall **STOP** and seek the advice of the responsible laser owner/operator, and/or the LSO/ALSO. No changes to procedures can be made without approval by the owner/operator.

6. Definitions:
    a. Operation – use of laser systems; will involve energy adjustments via waveplate/polarizer pairs already in place.
    b. Gross alignment – any procedure where beams are not already on optical components, or those that may lead to beams leaving established paths and optical surfaces.
    c. Simple/normal alignment – procedures where beams do not leave established beam paths/optical surfaces/beam stops.

Operation SOP:

1. Except during alignment procedures, all primary and specular beams, as well as diffuse reflections from class 3b and 4 beams must be contained on the laser tables using non-combustible diffusely reflecting or absorbing laser beam stops that do not create hazardous vapors. Class 3b and 4 beams between tables across open floor space must be enclosed in protective tubes, except as specifically noted in the "Configuration" section above. All optics must be solidly attached to laser tables so that accidental "bumps" cannot send beams in unknown directions. Physical protection must be provided from vertical beams or any other situation where unexpected exposure might occur. Under these conditions, the nominal hazard zone is confined to the areas above the laser tables, and eye protection as specified below is required for work within the nominal hazard zone. *Any light outside the NHZ must be at levels at or below the maximum permissible exposure (MPE).*

2. Lasers should be operated at the minimum intensity consistent with experimental requirements.

3. Nd:YAG lasers must be used with enclosed termination of all unused harmonics.

4. Users must know and follow the routine operation instructions for all lasers as described in the manuals provided by the laser vendors. Users must also be familiar with the LEAF Laser System Manual and the procedures there for laser system turn on/off.

5. A common operation procedure is the adjustment of the amplifier pump energy, by rotating waveplates in the amplifier box. This does not involve moving any beams, however it does involve opening the amplifier cover thus users must:
    a. Wear eye protection for 800 nm.
    b. Be aware of the intense 532 nm pump beam because of the large skin burn hazard. Because of this hazard, eye protection for 532 nm is not required so that users can see the beam and know where not to put fingers or other items. However, this then requires exceptionally high attention and care be taken to avoid the possibility of causing a stray or diffuse reflection.
    c. Do not put any objects (fingers, watches, cards) in any beams.
    d. Only open the amplifier cover as much as necessary, and close the covers when done.

6. Another common procedure is measuring the output energy of the amplifier and it's third harmonic:
    a. Wear eye protection for invisible beams including both 800 nm and 266 nm.
    b. Do not put any objects (fingers, watches, cards) in any beams.

7. Special care must be exercised when using the OPA, due to the possibility of multiple wavelengths being present at the same time. Users of the OPA must be aware of which wavelengths may be present during use, and protect themselves and co-workers accordingly. While it is possible to determine the combination of possible colors by understanding the OPA operation, it can also be can be determined by using the tuning information normally stored next to the OPA for easy reference. In addition, the wavelength of the OPA output will be posted on the white board outside the LCA next to the box containing the laser safety eyewear as well as near the vault door if the OPA is being used in that area so that the correct eyewear can be worn by the next person to enter the LCA.

Alignment SOP:

1. There shall be no intentional intrabeam viewing with the eye!!

2. Maintain good housekeeping practices on laser tables; keep the area where you will be working clear of excess objects that might scatter a beam unpredictably, and keep combustible materials away from class 4 hazards.

3. Consider the use of low power class 1-3a coaxial CW alignment lasers when convenient.

4. During alignment procedures, only persons immediately involved in the procedure are to be in the LCA. These individuals must have appropriate training and be listed in this document as authorized laser users.

5. When it is possible that hazardous beams are not completely contained on the laser tables, the room must be posted with a temporary alignment warning sign on the door warning those that may enter not to until the procedures are completed and the sign removed.

6. During all times when the possibility for inadvertent exposure to laser light exists, appropriate laser safety eyewear must be worn. The appropriate ratings are listed in the PPE section, and discussed further below.

7. Definite termination of the beam path must be in place before the beam is allowed to propagate. Use moveable beam stops to ensure that uncontrolled propagation does not occur.

8. Alignment procedures are always to be performed with the minimum practical laser power levels and repetition rates. This is especially true for the output of the primary pump lasers. In the case of the Quanta-Ray Nd:YAG lasers this can be achieved by the use of long pulse mode that dramatically reduces the high-energy 532 nm output, and produces a much longer pulse width. Since you must be able to see this beam in order to align it, refer to the comments in #14 below. The beam energy can be further reduced if necessary by tweaking the harmonic generator off the maximum, though this is typically not useful since this will also move the beam some. Inside the TSA amplifier, use the waveplates to minimize the 532 nm energy to the point (nearly minimum) where a good quality beam is just visible before doing alignments.

9. Following a new laser beam set-up or change in alignment, a survey of the beam path will be conducted to verify that all unwanted beams and reflections have been properly terminated. Opaque barriers will be used to confine low intensity stray reflections and scattered light to the optical tables. Any unwanted primary or specular beams in excess of class 4 thresholds will be terminated in a beam stop within the NHZ that does not produce hazardous diffuse reflections.

10. Gross alignment of beams from class 4 lasers into experiments or tunable lasers should be done with beams attenuated as far below class 4 thresholds as possible, with eye protection adequate for the beam in use.

11. Routine laser-specific alignment procedures may be simple or complex. Where they exist, specific procedures outlined in the operation and alignment manuals supplied by the manufacturers must be followed.

12. Pre-position optical components during gross alignment as best as possible and bolt them down before allowing beams to propagate.

13. Be aware of the potential for errant reflections (stray beams) from and leaked beams transmitted through components such as polarizers and dielectric mirrors. For example, do not use or rotate calcite polarizers with escape windows without first being sure that all exit beams will be blocked. Check for stray beams at each step and again after completing all alignment steps.

14. In some circumstances, it may not be possible to perform certain alignment tasks while wearing blocking eyewear. Unobstructed viewing of diffuse reflections is a last recourse, after exhausting

other possibilities like power meters, viewers and emissive cards. In cases where it is necessary to view diffuse reflections of visible beams in order to perform an alignment, the following apply:

a. If you are not absolutely sure about the safety of the procedure you are doing, stop and seek assistance from the appropriate PI and/or other reference person such as the department LSC or BNL LSO/ALSO.
b. Heightened awareness of beam hazards is necessary during such procedures. Special care and planning is needed to insure that unexpected specular reflections do not occur, and that hazards from other beam sources are controlled.
c. Be sure that diffuse viewing is non-hazardous. Consult the MPE table above and the eyewear PPE table below for information about diffuse reflections of the primary laser sources. See also the discussion in the eyewear section on some specific procedures, as well as general methods to limit the hazard to below the MPE by using primarily lower power, distance from the source, and viewing time.
d. Use the minimum possible energy consistent with the task at hand.
e. Discuss new procedures with a colleague in order to identify safe methods.
f. Use only cards without shiny surfaces to produce only diffuse reflections, and angle cards away from the face to avoid any possibility of specular reflections.
g. Minimize viewing time of the beam on a card; often only a second or two is necessary to align a beam.
h. Replace eyewear immediately upon completing task. Often it is enough to simply momentarily raise glasses without removing them at all.
i. Do not put your face close to the source of diffuse reflections; use cards at arm's length away when possible.

Maintenance SOP:

1. Certain approved laser users will conduct occasional routine maintenance. This includes procedures such as replacement of the flash lamps and cooling water in the Nd:YAG lasers, optics cleaning and/or replacements in all lasers. All of these procedures are to be conducted in strict accordance with the methods described in the laser manuals provided by the manufacturers if they exist, and only by individuals with appropriate training who are listed in this document. Any maintenance on BNL constructed equipment will only be performed under the direction of the appropriate PI.

2. Non-routine maintenance and troubleshooting is a serious matter, as injury or damage to equipment could result from actions taken in unfamiliar circumstances. When an uncharacterized fault condition exists, some actions that would be safe under ordinary conditions may have unsuspected hazards. Diagnostic work on optics or electronics will thus only be undertaken strictly following specific instructions in the manufacturer's laser manual, or in consultation with the manufacturer's service engineering staff. When there is any uncertainty about the safety of a diagnostic procedure, don't do it, and seek additional expert guidance. The laser manufacturer's field service engineers may be required to perform specialized maintenance tasks for which lab employees lack specific expertise and training.

3. In certain cases maintenance of laser components requires working with the laser interlock defeated, usually the interlock on the laser head case. Under these conditions there are several additional hazards one must be aware of. As discussed earlier a high voltage area is exposed. To minimize the risk of accidental touching, plastic covers are used to mask these areas. They will be replaced if they must be removed for the maintenance work, before the laser is operated again. Another issue one must be aware of is the increased amount of IR light present and also the possibility of an increased amount of second harmonic light (532 nm) in the Nd:YAG head. This requires one to double check the protective eyewear being worn to minimize the possibility of stray light entering eye. The last issue is when the cooling water is replaced. In this case, the

laser power supply cabinet cover is removed. To minimize risk of energizing the power supply the water pump will be run with the interlock enabled, which gives ~60 seconds before the power supply shuts down and does not allow the lamps to flash. In addition, users will position themselves and the power supply to maintain a safe distance from potentially energized components.

4. Procedures that the laser manufacturer's field service engineers perform may contain additional work under defeated interlocks. In these cases, Brookhaven personal overseeing the engineer will maintain a safe distance from any open electrical hazards and wear all relevant PPE.

CONFIGURATION CONTROL

A checklist must be developed for the purpose of verifying the placement and/or status of components that are used to mitigate hazards by configuration control. Examples include any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Entries should also be included to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

In general, engineering controls of the type describe above are not changed during normal operation. During routine operation and simple alignment procedures, certain laser covers may be opened or removed for short periods of time to allow for simple adjustments. After such operations, the covers are replaced and do not require rechecking of the full configuration control list below. In other cases however, such as during gross alignment procedures, more comprehensive work is done. In such cases, the room must be posted with an alignment warning sign, which is not removed until the normal operating condition is restored with all controls back in place. This includes a sweep of the area to ensure that no beams or intense diffuse reflections leave the optical tables. The following checklist of items are finally required to be in place at completion of gross alignment before resuming normal operation:

1. Laser enclosure covers:
    a. All Nd:YAGs
    b. Ti:Sapphire oscillator
    c. Ti:Sapphire amplifier
    d. Pulse compressor
    e. Third harmonic generator
    f. OPA
2. Beam tubes:
    a. From Nd:YAG pump to amplifier box (large energy)
    b. From third harmonic generator to energy control section (inadvertent exposure)
3. Beam dump for 1064nm light from Lab170 Nd:YAG when it is in operation
4. Shutters:
    a. UV shutter providing vault interlock
    b. Probe shutter providing vault interlock

Since this laser system is used for a wide variety of research topics, changes in beamstops, optical components and subsequent optical paths are common. Such changes must be consistent with the safety envelope defined by this document. When changes occur, the following procedures must be followed:

1. Communication with other users and the owner/operator is crucial. This can be accomplished by posting a sign on the door to the LCA to note changes, or using the white board by the laser room door. In some cases where procedural changes are required, contacting all of the people who use the LCA may be necessary.
2. After making any changes, the area must be checked to be sure that no new hazardous condition is created. This involves items described in the alignment section of the SOP above, key among which are that beams are all in well defined paths, and confined to the optical tables.

PERSONAL PROTECTIVE EQUIPMENT

☐ Skin Protection ☒ Eye Wear

Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE) describe the nature of the hazard and the steps that will be taken to protect against the hazard.

The 266 nm Nd:YAG harmonic of some lasers in this facility may have intensities in excess of skin MPE. UV beams propagated across otherwise accessible floor space will be enclosed to prevent skin exposure. Operators will minimize risk of skin exposure by:

1. Using reduced power during alignment procedures where possible.
2. If not possible to avoid exposure or reduce the power far enough, then wear long sleeves and other skin protection during alignment procedures.
3. Enclose class 4 beams in rigid tubes where personnel are likely to intercept them.

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury:

a. During normal operation, protection from invisible beams is always required, but it is not necessary to wear eyewear protection against all visible wavelengths provided all beams are controlled as described in the operation and alignment SOPs above. The key features of this requirement are that all beams are enclosed in the NHZ, and no adjustments to visible beams are being made.
b. Alignment of the amplifier 532 nm pump beam will require removal of visible eye protection. This is discussed along with precautions in the alignment SOP above. A key feature of this procedure is running the Nd:YAG in long pulse mode to drop the peak power and total energy/pulse (actual energy varies). Be aware however that while far safer, this beam is still hazardous, and has an energy high enough to cause eye damage for specular reflections. In normal circumstances, this beam is easily viewable on the optics without the need for diffusely reflecting cards. Special care and thought must be taken if the beam must be grossly steered to insure it does not cause hazardous reflections. Diffuse beam viewing may be needed and is permissible with cards as long as it is only momentary (< 6 seconds) and at the greatest possible distance (> 40 cm).
c. Alignment of visible 3b diode modules in the vault may require unprotected diffuse viewing, as IR viewers and upconversion viewing cards do not work sufficiently. When this must be done, precautions in the alignment SOP must be followed. This will only be done while the

diodes are pulsed (not CW) as noted in the laser characteristics above. In this circumstance while only marginally hazardous, the required intrabeam ODs are 1.0-1.3 and thus require heightened awareness and care. Diffuse reflections from cards typically used for alignment are safe provided reasonable care is taken.

d. For alignment of the quantum cascade lasers, safety glasses with an OD of 2.1 (intrabeam) are appropriate for 100mW beams, and no glasses are required for diffuse reflections. Polycarbonate glasses will be used when the IR beam is exposed for alignment in the control room (when the shields are not in place). If the actually measured IR power is more like 10mW, required ODs drop to 1.1, and glasses will not be worn.

e. Internal alignment of the OPA may require unprotected viewing. As noted in the Operation SOP, this device generates many concurrent different wavelengths, and as such requires heightened care during alignment. At a bare minimum, protection for the pump beam at 800 nm is mandatory, and special precautions such as those listed in the Alignment SOP are required. Awareness of which wavelengths are present where and when in the OPA is needed; this is detailed in the manual. Typically the pump for last stage of amplification is blocked with a card, and OPG and white light spots are viewed using a diffusely reflecting card after the first and second stages of amplification. In these cases diffuse viewing does not require eye protection. Final alignment is done by viewing a variety of differently colored spots on a card external to the OPA in order to overlap them. During this procedure, viewing must be done for as short periods as possible (< 6 seconds) and at distances as long as possible (> 40 cm) to reduce the hazard below the MPE.

f. Alignment of visible output from the OPA may require unprotected viewing in both the laser room and vault. Again, precautions detailed ion the Alignment SOP above must be followed. In particular extra caution and planning is needed to avoid the possibility of specular exposure including definite termination of the beam and coworker awareness must be observed. As before, most alignment will be accomplished using diffusely reflecting cards. To avoid hazardous exposure, viewing must be momentary (< 6 seconds), and at arm's length (> 40 cm).

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

EYE WEAR SPECIFICATIONS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density *	NHZ ** (meters)	Appropriate Eye Wear ***
1. Spectra Physics Millennia Vi diode-pumped Nd:YVO4	532 nm	3.75	2.41	3.24	L228
2. Spectra Physics Tsunami Ti:Sapphire Oscillator	798 nm	3.12	N/A	N/A	L568
3. Quanta-Ray GCR 170-10 Nd:YAG	1064 nm‡	6.15	3.08	6.9	L568, L228
	532 nm	6.47	3.80	15.9	L228
	266 nm	5.58	2.16	2.4	L568, L228, GBM-64-N
4. Quanta-Ray Pro-290-30 Nd:YAG	1064 nm‡	6.42	3.35	9.5	L568, L228
	532 nm	6.72	4.05	21.2	L228
5. Positive Light TSA-10 Ti:Sapphire Amplifier	800 nm	6.32	3.25	8.4	L568
	800 nm	5.56	2.49	3.5	L568
6. Homebuilt pulse compressor	800 nm	6.02	2.95	6.0	L568
	800 nm	5.54	2.47	3.4	L568, GBM-64-N
7. Homebuilt tripler	400 nm	5.51	2.85	5.3	L228
	266 nm	3.33	N/A	N/A	L568, GBM-64-N
8. Quantronix Topas 4/800 Optical Parametric Amplifier†	200-400 nm	2.17	N/A	N/A	L568
	400-700 nm	4.62	1.95	1.9	
	700-1050 nm	4.74	1.67	1.4	L568
	1.05-1.20 um	3.91	0.85	0.5	L568
	1.2-1.4 um	3.31	0.24	0.3	L568
	1.4-2.6 um	1.90	N/A	N/A	
9. Power Technology Inc. PMT70(658-80B)G2	658	1.86	0.53	0.05	L568
	658	1.30	N/A	N/A	L568
10. Power Technology Inc. PMT120(808-150B)G2	808	2.27	N/A	N/A	L568, GBM-64-N
	808	1.72	N/A	N/A	L568, GBM-64-N

11. Power Technology Inc. PMT(LD1415)G2	639 639	1.55 1.0	N/A N/A	N/A N/A	L568 L568
12. Power Technology Inc. PMT(LD1438)G2	685 685	1.79 1.23	N/A N/A	N/A N/A	L568 L568
13. Power Technology Inc. PMT90(980-100B)G2	980 980	1.85 1.29	N/A N/A	N/A N/A	L568, GBM-64-N L568, GBM-64-N
14. Power Technology Inc. PMT32(1300-50B)G2	1300 1300	0.51 N/A	N/A N/A	N/A N/A	L568 N/A
15. Power Technology Inc. PMT27(1550-40B)G2	1550 1550	1.71 N/A	N/A N/A	N/A N/A	L568 N/A
17. Daylight Solutions Quantum Cascade Laser Model 21052-MHF	5102-5294 nm	1.80	N/A	N/A	Measured and certified polycarbonate (MSA Z87+)
18. Daylight Solutions Quantum Cascade Laser Model 21049-MHF	4798-5010 nm	1.80	N/A	N/A	Measured and certified polycarbonate (MSA Z87+)

* Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewed normal to the surface. The ODs required can decrease for more typical conditions in the laboratory:

a. Every time the viewing distance doubles, the OD goes down by 0.6
b. Generally, the OD drops by ~1.0 for each factor of 10 shorter in the viewing time
c. For a 45 degree to the normal viewing angle, the OD drops by 0.15
d. For reflectivities lower than 1, the OD will drop by $\log_{10}$[reflectivity]
e. As the energy/power drops, the OD will drop by $\log_{10}$[I/I0]

Thus for example, the alignment of the 800 nm probe beam, derived from source #8 can be done without safety glasses if: a) viewing distance is at arm's length to diffusive card (my arm ~ 80cm) drops OD by 1.2; b) viewing time is ~2 sec drops OD by 2.5; e) energy after beams splitters ~1 mJ (a third) drops OD by 0.5 for a net OD drop of 4.3 making glasses unnecessary for diffuse viewing only. Note that the intrabeam hazard is unchanged.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable or even preferable provided the optical densities are equivalent or greater than those required. Note that some of these beams in the vault area are not as intense as in the laser room, thus appropriately lower ODs are acceptable. Under normal operation since visible beams such as 400 and 532 are controlled, the best choice for glasses are the Uvex L568, as they block all of the invisible beams but leave a fairly good visual throughput.

† ODs depend greatly on wavelength; OD listed is the minimum for each range shown. Due to the broad range of output colors of the OPA, users must use good sense in selecting appropriate eyewear during alignment. In some cases it will not be possible to have eyewear to protect from all available wavelengths, in which case the user must use extreme care, and follow the rules in #14 of the alignment SOP above.

‡ 1064 nm outputs are normally terminated inside the laser cabinets, or at the exit in an external beam dump, and in this condition require no eye protection.

EYE WEAR SPECIFICATIONS

Laser System Eyewear Identification				Wavelengths (nm)	Optical Density
#	Model	Type	Color		
4	Uvex L568	Spectacle		200-350 † 633 750-1050nm 1050-1064nm 1064-1300nm † 1300-1400nm † 1400-1580nm † 10600nm	5.8+ 1-2 7+ 8+ 5+ 4+ 2+ 5+
2	Uvex L228	Spectacle		190-532nm 633nm 750-1050nm 1050-1064nm	8+ 1-2 7+ 8+
1	Uvex L328	Goggle		633nm 190-532nm, 750-1050nm 1050-1064nm	1-2 8+ 7+ 8+
1	Uvex L267	Spectacle		190-532nm 1050-1064nm 10600nm	8+ 8+ 7+
3	GPT Laser Gard Argon NDGA #2175	Goggle		353nm 530 1060nm	20 7 10
1	GPT Laser Gard LGB	Goggle		200-400nm 488 514.5nm 530nm 840 1060nm	14 11 7 4 4 4
2	GPT/Glendale GBM-64-N	Spectacle	Amber	190-532 520-532 710-750 750-850 790-810 ‡ 850-1080 5000-11000	9+ 7+ 3+ 5+ 5.8+ 7+ 7+

EYE WEAR SPECIFICATIONS					
Laser System Eyewear Identification				Wavelengths (nm)	Optical Density
#	Model	Type	Color		
2	GPT/Glendale GBG-64-N	Goggle	Amber	190-532 520-532 710-750 750-850 790-810 ‡ 850-1080 5000-11000	9+ 7+ 3+ 5+ 5.8+ 7+ 7+
3	(MSA Z87+)	Goggle	Clear	> 1000 nm †§	4.3+

For normal conditions, appropriate eyewear for each area is stored in clear compartment boxes mounted on the walls at the entry to both the LEAF laser room and vault.

† Glasses not marked for these wavelengths. Data from testing in our lab; results are stored in LCA notebook.

‡ Glasses not marked for these wavelengths. Data provided by Kentek Corporation; results are stored in LCA notebook.

§ When quantum cascade laser are used, the beam path will be delineated with a yellow chain to prevent persons from walking through the beam.

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to assure that they can identify and control the risks presented by the laser systems they use. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL World Wide Web based training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

All laser safety training must be repeated every two years.

SOP SIGNATURES

The signatures of the personnel listed in the following table indicate that these personnel have read and understood the contents of this SOP and agree to adhere to the guidelines detailed in therein. The signature of the Owner/Operator indicates that the Owner/Operator has reviewed this SOP with the User to ensure that its contents have been clearly communicated and understood.

SOP Signatures are necessary but do not document complete authorization. Other required training elements and documentation are described immediately above in the "Laser Safety Training" section. Only persons who have signed below, and completed/have documented the required training may operate the lasers covered by this SOP.

User Printed Name	Signature	Date	Owner/Operator Signature
Owner: Andrew Cook	———		
Owner: James Wishart	———		
John Miller			
Jack Preses			

Training certification for laser users in building 555 rooms 23,25 (LEAF)

Training for Laser User:	
On laser system:	All lasers at LEAF

Topic	Signature of user/date (Initial of laser owner)
Instruction in interlock configuration for laser access restricted area (room or enclosure)	
Description of laser output characteristics (wavelength, pulse energy, length of pulse and/or average power)	
Checklist of major hazards (including laser light, compressed gases, cryogens, electrical): • Wear eye protection for invisible beams at all times when laser emission is possible. This includes both the laser room and the vault. • Never intentionally direct a beam towards your face, or put your face in line with any laser beam: **do not depend on eyewear to protect you**. • Be aware of what your co-workers are doing, and alert them to any potentially hazardous conditions or actions. • Do not enter areas posted with an alignment sign unless you have permission. • Use minimum laser power possible during alignment. • Use plain or fluorescent sensor cards or IR viewers when possible to aid in locating laser beams. • Locate all surface reflections and terminate with appropriate beam dumps. • Use *COMMON SENSE* and *CARE* in performing all alignments. Think about the consequences of your actions, as it pertains to the safety of yourself, others and equipment. • If unsure about what you are doing, STOP! Ask a knowledgeable person what to do before proceeding. • Don't grossly align lasers at high power. • Don't place optical elements into the laser beam without first blocking the beam with an appropriate dump. • Don't wear any reflective materials (such as rings, watches, BNL badge) on your hands or arms, or around your neck during the arraignment. • No *unauthorized* personnel are allowed in the laboratory during laser operation. • When adjusting the amplifier pump energies, take care not to put objects and/or fingers in the pump beam.	
Operation: Power on/off, shutter operation, normal experimental configuration, nominal hazard zone where class IV intra-beam beam protection is required, adjustment of beam energies via waveplate/polarizers.	
Simple Alignment: UV on cathode, minor experimental alignment (delay line, vault experimental table).	
Normal maintenance: Changing laser lamps, filters.	
Non-normal operation: Replacing damaged laser components, gross alignment, new optical systems, amplifier/internal laser alignment, etc..	

BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system listed below. All American National Standard Institute (ANSI) Hazard Class 3b and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed annually.

System description: **Soft Matter Physics Group, Optical Microscopy System for Organic Thin Films**

Location: **Bldg 510, the optics lab (inner room) inside Room 2-106 (CMPMSD space)**

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator for this laser is listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:

Name: **Masafumi Fukuto** *Signature:* Masafumi Fukuto *Date:* 3/17/09

AUTHORIZATION

Work with all ANSI Class 3b and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required.

Jack Preses	Jack Preses	3/17/09
BNL LSO printed name	*Signature*	*Date*
C. Weilandics	C. Weilandics	3/25/09
BNL ALSO printed name	*Signature*	*Date*
[illegible]	[illegible]	3/17/09
Department ES&H Approval printed name		*Date*

APPLICABLE LASER OPERATIONS
☒ Operation ☒ Maintenance ☐ Service ☐ Specific Operation ☐ Fiber Optics

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls.

LASER SYSTEM CHARACTERISTICS

Laser Type *(Argon, CO_2, etc.)*	Wavelengths	ANSI Class	Maximum Power or Energy/Pulse	Pulse Length	Repetition Rate
Argon-Ion (Air-cooled; Spectra-Physics, Model: 177-G12-FBR)	**488 nm**	**IIIb**	New tube, without fiber coupling: **200 mW/CW** New tube, with fiber coupling: **140 mW/CW**	N/A	N/A
Diode	**670 nm**	**3R**	**1 mW/CW**	N/A	N/A

☐ **Cryogen Use**
Describe type, quantity, and use.
NOT used.

☒ **Chemicals & Compressed Gasses**
Describe type, quantity, and use.

- **Chemical use is limited to sample preparation and handling, which are covered under the Experimental Safety Review PM2008-74 (Title: "Soft Matter Chemical Procedures and Instrumentation").**

- **Compressed air is used to activate the vibration isolators in the optical table posts. (For proper set-up and operation of the vibration isolation control, consult the "*General Instructions*" booklet for TMC MICRO-g Vibration Isolation Systems.) The compressed air is supplied through Polyflow tubing that is fixed to ceiling and walls and is connected to a compressed air cylinder located outside Rm 2-106. The gas cylinder shall be equipped with a regulator and shall be fastened to the wall mount in the hallway on the north side of Rm 2-106 (the wall opposite to the men's room). The supply line pressure shall not exceed 100 psi. When the vibration isolator is not in use for an extended period of time, close the main valve of the cylinder and depressurize the gas line.**

☒ **Electrical Hazards**

Description *(Describe the power supply to the system).*

The power supply (Spectra-Physics, Model 277-GA01) is external to the laser head and is as supplied by the manufacturer. The input is rated at 220 VAC, 60 Hz, 16 A max. The minimum output is 70 VDC at 4.0 A, and the maximum output is 220 VDC at 12.0 A. Potentially lethal voltage levels exist inside the power supply.

☒ **Other Special Equipment**

Description *(Equipment used with the laser[s]).*

* **Nikon optical microscope**

The Nikon 80i microscope is used to inspect samples with small features. The microscope can operate in either transmission or reflection mode and therefore requires 3 light sources, two halogen lamps and one mercury lamp. All three lamps came as part of the microscope unit and are as provided by the supplier. The mercury lamp is used for fluorescence microscopy and its spectrum extends to UV range. The UV part of the spectrum is attenuated by filters and does not pose hazard to eyes. An absorbent visor is also installed to block off possible stray UV rays reflected by the sample. However, the lamps do generate a lot of heat and the microscope should not be covered until the lamp houses cool down to room temperature. In general the halogen lamp should be turned off when not in active use to prolong the lamp life. In contrast, the mercury lamp should be left on during short intervals between observations, since frequently turning it on and off reduces its lifetime.

* **CCD camera**

Captures images of organic thin films; the image is formed by the light that is either fluoresced or reflected by the film. The power should be kept OFF during sample handling and turned ON only during the measurement. The unit should be properly encased during operation; never operate with its cover off. Be careful to avoid saturation.

* **Sample cells**

Organic thin films to be imaged are formed at various interfaces. Preparation and control of these films require different sample cells depending on the type of interfaces:

- **Langmuir troughs for films at liquid/vapor interfaces: There are a few instruments of this type in our laboratory. Each of them contains i) a shallow container ("trough") that holds water or an aqueous subphase, on the surface of which a thin organic film is spread; ii) a moveable barrier that is computer-controlled to vary the area of the film-coated surface; iii) a surface tension balance; and iv) a cooling plate underneath the trough for temperature control.**
- **Flow cells for films at liquid/solid interfaces: A sealed cell contains a substrate and is filled with water or an aqueous solution.**
- **Sample cells for films at solid/vapor interfaces (film-coated substrates): A sealed cell contains a substrate and a liquid reservoir and is filled with the vapor of the liquid. The temperature and/or the vapor pressure are controlled.**

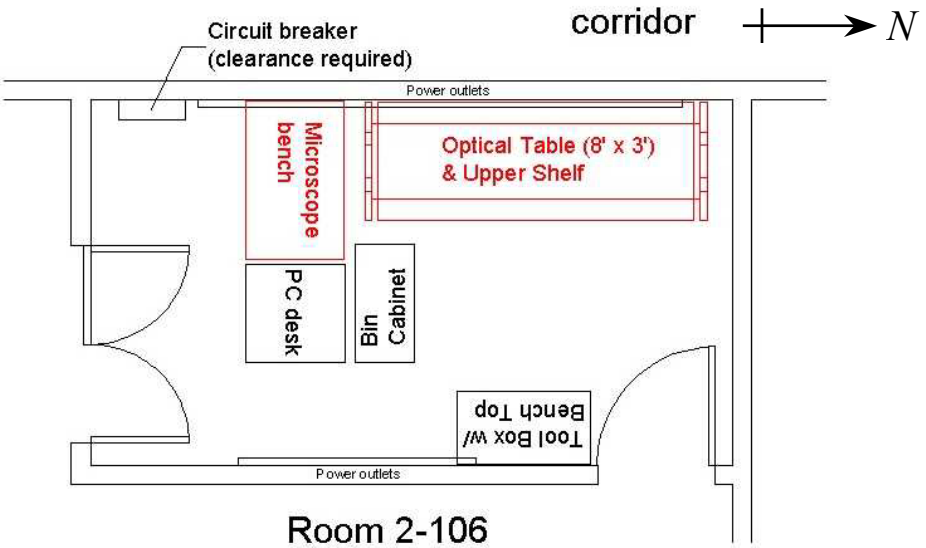
Handling of the sample presents a potential risk for water spills. With the exception of sample cells and the CCD camera, DO NOT place any electrical/electronic devices, controllers or power supplies close to (within a foot of) the sample area on the optical table or on the microscope stage, and make sure that all such devices are properly encased/enclosed.

* **Neslab water circulators/chillers [NOT for cooling the laser head]**

Used to control the temperature of the Langmuir troughs; see the sample cell description above. The circulator unit must be placed on the floor. Make sure that there are no leaks in the plumbing/tubing.

Laser System Configuration: Describe the system controls (*keys, switch panels, computer controls), beam path, and optics (provide a functional/block diagram for complicated beam paths*).

OPTICS LAB LAYOUT



SYSTEM CONTROLS

Keys:

- **A key switch on the power supply unit (Spectra-Physics, 277-GA01) turns on/off the power supply to the laser head.**

Switch Panels:

- **Front panel of the power supply unit (Spectra-Physics, 277-GA01), as provided by the manufacturer. One switch is for turning on/off the AC power and the cooling fans on the power supply and the laser head. The other is the key switch for turning on/off the laser. See *Spectra-Physics Model 177-Series Laser Systems User's Manual.***

- **Remote control module (Spectra-Physics, 377-G10), as provided by the manufacturer. The controller is equipped with power INTERLOCK jumper that needs to be shorted for laser operation. The unit allows the user to turn on/off the laser and control laser output either via laser output power or via plasma tube current. See *Spectra-Physics Model 177-Series Laser Systems User's Manual.***

- **Black "Interlock Box". This unit controls i) shorting/opening of the power INTERLOCK jumper on the remote controller, ii) illumination of the warning signs outside the**

entrances, and iii) opening/closing of the laser-head shutter, which is interlocked with the entrance doors. See the descriptions in Engineering Control section below and the interlock documentation.

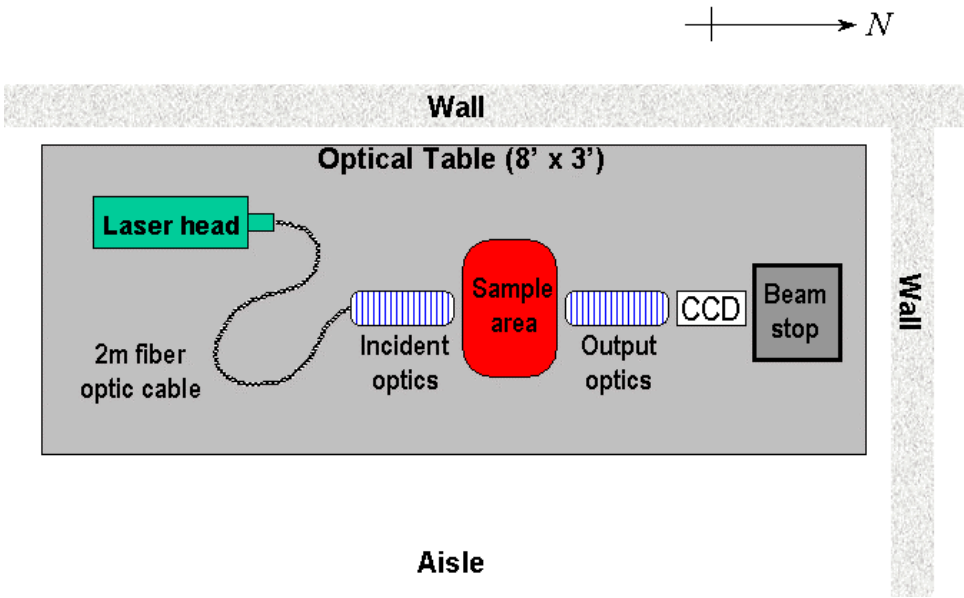
- **Black "Laser Shutter" box located on the outside wall near one of the two entrances. A push-button switch on this box allows a user to open the laser shutter from outside the room. See the descriptions in Engineering Control section below and the interlock documentation.**

<u>Computer Controls</u>:
NONE

<u>BEAM PATHS and OPTICS</u>

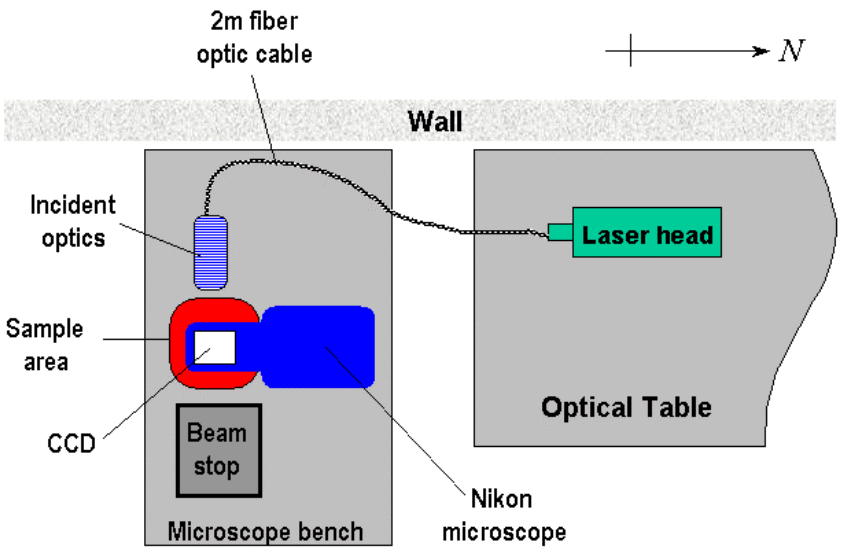
A given experimental setup shall conform to one of the following two general configurations:

Configuration 1: Experiments without Nikon microscope



- **Incident and output optics may contain any of the following: apertures, mirrors, lenses/objectives, polarizers, retardation plates, and dichroic filters.**
- **Output optics and CCD can be positioned <u>in any direction and orientation</u> around the sample area (the above figure shows one such example).**
- **Laser beams shall be actively terminated with the use of a beam stop and beam blocks.**
- **Under normal operation, laser beam shall remain on the optical table.**

Configuration 2: Experiments where laser is used in conjunction with Nikon microscope



- **Incident optics may contain any of the following: apertures, mirrors, lenses/objectives, polarizers, and retardation plates.**
- **NEVER direct the laser beam through/along the optical axis of the Nikon microscope. That is, the direct or specularly reflected laser beam is NOT allowed to enter the microscope objective. Only diffuse-scattered or fluorescence light is allowed to enter the microscope objective. [Any change to this rule requires a modification of the present SOP and a review and re-approval by the Laser Safety Officer.]**
- **Laser beams shall be actively terminated with the use of a beam stop and beam blocks.**
- **Under normal operation, laser beam shall remain on the optical table and the microscope bench.**

DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

Recognition, evaluation, and control of laser hazards are governed by the following documents.

American National Standards Institute (ANSI) Standard for Safe Use of Lasers;
(ANSI Z136.1-2000)

Laser Safety Subject Area

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL

ENGINEERING CONTROLS

☐ Beam Enclosures
☐ Protective Housing Interlocks
☒ Other
☒ Beam Stop or Attenuator
☒ Key Controls
☒ Activation Warning System
☒ Other Interlocks
☐ Ventilation
☒ Emission Delay

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review, a copy of the design review documentation and written testing protocol must be on file. Completed interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

☒ **Beam Stop:**

☒ **Activation Warning System:**

i) Red indicator lamp for the "MAIN" switch of the Interlock Box. Flipping the MAIN switch ON lights up the indicator and shorts the "INTERLOCK" jumper on the remote control module (Spectra-Physics 377-G10), which is necessary to allow the laser power to turn on. Thus, the glowing MAIN lamp indicates that the laser CAN BE turned on.

ii) "LASER ON" warning signs, located outside and above the two entrances to the room. These signs are illuminated also when the MAIN switch on the Interlock Box is turned ON, i.e., whenever the laser CAN BE powered on.

iii) RED power-on/emission indicator on the front panel of the laser power supply unit (Spectra-Physics 277-GA01). The indicator glows when AC power is applied to the system, the DC regulators are powered up, and emission is present or imminent.

iv) Display on the remote control module (Spectra-Physics 377-G10) indicates either the laser output power or the plasma tube current, depending on the setting of the "POWER/CURRENT DISPLAY" switch.

☒ **Key Controls: Located on the laser power supply unit (Spectra-Physics 277-GA01).**

☒ **Other Interlocks:**

Laser-head shutter interlock. The safety shutter on the laser head (as supplied by the manufacturer) is mechanically coupled to a spring-loaded solenoid, whose activation is controlled by the Interlock Box, the "LASER SHUTTER" box located outside near one of the two entrances, and the limit switches on the entrance doors. If

i) the MAIN switch is ON, and
ii) the SHUTTER switch is at the "ENABLE" position, and
iii) all the doors are closed,

then,

a) pressing the SHUTTER "OPEN" push-button switch on the Interlock Box, or
b) pressing the push-button switch on the LASER SHUTTER box outside,

powers up the solenoid and opens the shutter. Whenever any one of the doors is opened, the power to the solenoid shuts off, and the shutter is closed by the springs. After the door is re-closed, the shutter remains closed; in order to reopen the shutter, one of the two push-button switches [a) or b) above] must

be pressed. The RED "SHUTTER OPEN" lamp on the Interlock Box and the RED lamp on the "LASER SHUTTER" box outside glow only if the shutter is physically open, by means of the magnetic switch located on the shutter coupling.

☒ **<u>Emission Delay</u>: 30 sec delay whenever following a hard reset on the laser power supply (i.e., after the filament current is turned off), including the opening of the "INTERLOCK" jumper on the remote control module (Spectra-Physics 377-G10). Note that this does not apply if the beam is turned off with the "DISCHARGE" switch on the remote controller, which turns off the plasma tube current but keeps the filament current on, so that there is no emission delay when the DISCHARGE switch is turned back on.**

☒ **<u>Other:</u>**

Protected laser-head housing. Although not interlocked, the housing of the laser head is an enclosed system and requires tools to disassemble and expose the inside. There is no cover that would just come off freely.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☒ Operating Limits

The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer.

All lasers must have a standard label indicating the system's wavelength, power, and ANSI hazard class. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Standard Operating Procedures (SOPs) are required for laser system operation, maintenance (including alignment), and servicing. The SOPs need only contain the information necessary to perform these tasks and identify appropriate control measures including postings and personal protective equipment. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Administrative Controls Description:

☒ **Laser Controlled Area: The entire space inside the optics lab room (the small room inside Room 2-106).**

☒ **Signs:**
- **i) Standard "DANGER" signs posted on the doors of the optics room.**
- **ii) "LASER ON" warning signs above the doors (also see the Engineering Control section above).**
- **iii) Signs posted on the doors of the optics room that indicate the next due date for the semi-annual interlock test and the fact that the user is not allowed to activate the laser if the interlock test is overdue.**

☒ **Labels: On the laser head (Spectra Physics 177-G12-FBR) and the power supply unit (277-GA01), as provided by the manufacturer.**

☒ **Operating Limits:**
Configuration 1: Experiments without Nikon microscope.
Under normal operating conditions [i.e., after the system is aligned], laser beams and the target must remain on the optical table.

Configuration 2: Experiments where laser is used in conjunction with Nikon microscope.
Under normal operating conditions [i.e., after the system is aligned], laser beams and the target must remain on the optical table and the microscope bench. The laser beam is used only to illuminate the sample or excite fluorescent probes in the sample. The direct or specularly reflected laser beam is NOT allowed to enter the microscope objective, and only diffuse-scattered or fluorescence light is allowed to enter the microscope objective.

CONFIGURATION CONTROL

A checklist must be developed for the purpose of verifying the placement and/or status of components that are used to mitigate hazards by configuration control. Examples include any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Entries should also be included to ensure placement of required signs and labels and status of interlock verification. Completed checklists must be posted at the laser location. The checklist does not have to be redone unless there has been a system modification, extended shutdown, or change of operations.

STANDARD OPERATING PROCEDURES

i) Normal Operations

- **Check to make sure that the semi-annual testing of the interlock system is up to date. If overdue, completion of the interlock checks is required before a user is allowed to use the laser.**
- **Before starting the laser, check to make sure that both of the two warning signs outside are illuminated with all four light bulbs lit (2 bulbs per sign). If a light bulb is burned out, have it replaced before proceeding.**
- **Before starting the laser, check to see that all the doors to the optics lab are closed.**
- **Laser power shall remain off and shutter closed during sample handling. Check to make sure that there is no water leak on the optical table or on the floor.**
- **Check to see that all the electrical devices other than the sample cell and the CCD camera are at least a foot away from the sample area.**
- **Check to make sure that all bending mirrors and other necessary optics are in place such that the intended optical paths will be followed by the laser beam.**
- **Laser shall be operated only by a trained user listed on the qualified laser user list.**
- **When laser is in use, only the listed users may enter the optics lab. Neither an untrained personnel nor a visitor is allowed in the room unless approved by the ES&H Coordinator or the Department Chair.**
- **The CCD camera shall not be exposed to room light or the laser beam while being energized.**
- **The space in front of the optical table shall not be blocked at any time.**
- **The laser beam shall be actively terminated with a beam stop at the end of its normal path and any possible alternate path(s).**
- **The laser beam should never be routed at normal eye level, typically heights between 1.3 and 2.0 m above the floor.**
- **Objects capable of specular reflections should be avoided on the optical table and on the user, *e.g.*, jewelry.**
- **When used in conjunction with the Nikon microscope, make sure that the laser beam will NOT go though/along the optical axis of the microscope; that is, the direct or specularly reflected laser beam is NOT allowed to enter the microscope objective.**

Only diffuse-scattered or fluorescence light is allowed to enter the microscope objective.

- **Turn on laser only after all steps above have been completed.**
- **Under normal operations (i.e., after alignment) where laser is used without the Nikon microscope, laser beams and the target must remain on the optical table.**
- **Under normal operations where laser is used in conjunction with the Nikon microscope, laser beams and the target must remain on the optical table and the microscope bench.**

ii) <u>Maintenance: General Alignment</u>

- **Attenuate the beam as much as possible, but to the extent that the beam is still visible through the safety glasses.**
- **All normal operating procedures shall be followed during alignment of the laser and the optical system.**
- **When used in conjunction with the Nikon microscope, make sure that the laser beam will NOT go though/along the optical axis of the microscope; that is, the direct or specularly reflected laser beam is NOT allowed to enter the microscope objective. Only diffuse-scattered or fluorescence light is allowed to enter the microscope objective. [Any change to this rule requires a modification of the present SOP and a review and re-approval by the Laser Safety Officer.]**
- **Any changes in optical configuration required for alignment but not for normal operations shall revert to the normal configuration when alignment operations are completed.**

iii) <u>Maintenance: Fiber-Optic Cable and Coupling</u>

- **Fiber assembly is pre-aligned at the factory but may require fine-tuning during initial installation and after normal plasma tube replacement (only via service). If so, follow the fiber alignment procedure detailed in Chapter 4, pages 4-4 to 4-5 of *Spectra-Physics Model 177-Series Laser Systems User's Manual*. The General Alignment procedures described above shall be followed during the fiber alignment.**
- **The optics at each end of the fiber-optic cable assembly are NOT user-serviceable. Do not attempt to clean or service any part of the fiber-optic cable assembly. If there is a reason to suspect that the optics have been contaminated or broken and that service may be required, the laser owner/operator shall contact the manufacturer.**

iv) <u>Maintenance: Laser System</u>

[Also see Chapter 2, page 2-3 of *Spectra-Physics Model 177-Series Laser Systems User's Manual*.] In order to maintain the compliance of the laser system with Center for Devices and Radiological Health (CDRH) regulations, the following need to be verified either annually or whenever the system has been subjected to adverse environmental conditions

(e.g., fire, flood, mechanical shock, spilled solvents). <u>Check the three items below together with the semi-annual testing of the interlock system</u> (see the interlock documentation):

- **Verify that removing the two-pin INTERLOCK jumper connector on the remote controller (Spectra-Physics 377-G10) prevents the laser operation.**
- **Verify that the power supply key must be in the ON position before the laser will start, and that it can only be removed when in the OFF position.**
- **Verify that the mechanical shutter on the laser head actually blocks exposure to laser radiation.**

The General Alignment procedures above shall be followed during these tests. If any of these tests fail, laser owner/operator shall contact Spectra-Physics Lasers service center.

PERSONAL PROTECTIVE EQUIPMENT

☐ Skin Protection ☒ Eye Wear

Skin Protection: For UV lasers or lasers that may generate incidental UV in excess of maximum permissible exposure (MPE) describe the nature of the hazard and the steps that will be taken to protect against the hazard.

Eye Wear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Color - coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the precautions that will be taken to prevent eye injury.

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

EYE WEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
Argon-Ion Max. 200 mW	**488 nm**	**2.3 (0.25 sec)**	**N/A**	**< 20 cm**	• **THORLABS "LG3" Laser Safety Glasses** • **KENTEK "UVEX" Eyewear UXK-ARG-A**

* Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

EYE WEAR SPECIFICATIONS		
Laser System Eyewear Identification	Wavelengths	Optical Density [T = 10^(-OD)]
THORLABS "LG3" Laser Safety Glasses (recommended for normal operation)	**190 – 449 nm** **450 – 532 nm**	**> 5** **> 6**
KENTEK "UVEX" Eyewear, UXK-ARG-A (good for alignment)	**190 – 380 nm** **488 – 515 nm** **10,600 nm**	**7** **2 – 3** **5**

Subject Area: ***Laser Safety***

General Guidance for Laser Protective Eyewear

Effective Date:**Jan 23, 2015**

General Guidance for Laser Protective Eyewear is provided as a Word file.

Management System: ***Worker Safety and Health***

GENERAL GUIDANCE FOR LASER PROTECTIVE EYEWEAR

Experience has shown that laser eye accidents more frequently occur during alignment procedures. In many of these instances, a problem has been that AVAILABLE EYE PROTECTION HAS NOT BEEN WORN. There have been numerous accidents reported involving individuals who had eye protection within reach but did not wear it. The reason stated was that during "alignment" they need to see the beam and could not.

Often, eyewear designed for full protection often greatly reduces the possibility of seeing the beam. Thus a diffuse reflection cannot be seen during an alignment process. As a result, the eyewear is removed to accomplish the alignment task. So-called "alignment" eyewear is designed to allow a safe level of laser light to be transmitted through the filter. This requires viewing only diffuse (scattered light) reflections of the beam and never the direct beam. Usually the alignment eyewear does afford some limited-time protection for accidental direct beam exposure but it is never intended for such viewing.

Visibility of normal ambient light (luminous transmission, or LT) through the filter can sometimes be improved if the laser eyewear filters are designed for the task. For example, optical alignment with a modestly powerful continuous wave (cw) laser can be done using a filter type that reduces the laser power transmitted through the filter from a diffuse reflection to not only a "safe" level but also a level that is "comfortable" to view. This might be required during alignment of an optical system by a technician using a diffusely reflecting target "to see the beam" during the task. In these cases, the MPE used in the optical density determinations can be based upon an exposure time of 600 seconds. Often the design allows an optical density significantly lower than would be required using an 8-hour MPE criterion. This usually results in a filter of greater overall luminous transmission, hence superior visibility while wearing the eyewear. It is important to account for sources of direct or specular (mirror-like) reflections.

Since the option during alignment processes is to "cheat" and not wear protective eyewear, in essence, alignment eyewear provides an alternative to no eyewear at all.

THE BASIC REQUIREMENTS UNDER ANSI Z136.1

- Protective eyewear shall be worn whenever operational conditions may result in potential eye hazard.
- All laser protective eyewear shall be **clearly labeled** with the **optical density** value and **wavelength** for which protection is afforded.
- Protective eyewear should be **comfortable**, provide **adequate visibility** (luminous transmission) and prevent hazardous peripheral radiation.
- **Periodic frequent inspection** shall be made of protective eye wear to insure the maintenance of satisfactory filtration ability especially following exposure to hazardous Class 4 laser radiation. See “Care and Maintenance” section below.

FACTORS IN CHOOSING LASER PROTECTIVE EYEWEAR

- **Optical density (OD) of eyewear at laser output**: These will be based on the output of the lasers and the wavelength(s) involved. Optical densities stamped on older eyewear may be misleading in that damage may occur to the eyewear and power densities or irradiances implied by the OD. Optical densities in excess of 6 on many types will also have rather low figures for luminous transmission, or the amount of visible light they let through.
- **Visible light (luminous) transmission requirements**: This figure should be as high as practical. Laser protective eyewear with luminous transmissions of around 20% and less should be avoided.

- **Damage thresholds**: Different goggle materials have different damage thresholds. The manufacturer should be consulted for these specifications on resistance to damage from high average power or peak irradiances.
- **Need for prescription glasses**: Some protective eyewear types (i.e., spectacles) can have prescriptions built right into the eyewear. Other types (i.e., goggles and wrap-arounds) may able to fit over normal prescription eyewear, and be less expensive but may be bulkier and/or heavier and less comfortable. This will affect **comfort and fit**, as well as **peripheral vision** of the eyewear, which can discourage its use.
- **Degradation of absorbing media**: Plastic filter materials often offer greater impact resistance, lighter weight, and convenience of molding the eye protection into comfortable shapes. The disadvantages are that they are more readily scratched and the filters often "age" poorly in that the organic dyes used as absorbers are more readily affected by heat and/or ultraviolet radiation, which cause the filter to significantly darken. Plastic materials generally display a lower threshold for laser beam penetration. This may be offset somewhat by the fact that the absorbing media is contained throughout the matrix and is not subject to scratching or wearing off.
- **Strength of materials (resistance to shock)**: Not all-absorbing glass filters used for laser protection can be easily hardened and, consequently, may not provide adequate impact resistance. In some goggle designs, however, impact resistant plastic filters (polycarbonate) can be used together with non-hardened glass filters in a goggle design where the plastic is placed in front and behind of the non-hardened laser filter glass.

TYPES

Goggles: This type of eyewear fits closely on the face and can usually be worn over prescription eyeglasses. They are usually constructed with frame vents to minimize lens fogging and are generally larger and heavier than spectacles or wraps

Wraps: This design is composed of a frame with a single lens that covers both eyes usually lighter than spectacles/goggles. This design, similar to goggles, can usually accommodate prescription glasses worn underneath.

Spectacles: A frame that usually has two separate lenses with side shields can be made with vision-correcting prescription eyeglasses.

SOME HELPFUL HINTS

- Even if you are wearing laser protective eyewear, **never look directly into any laser beam.** Contact the Laser Safety Officer (LSO) if you feel that aligning your laser requires intrabeam viewing.
- If laser protective eyewear is required, the Standard Operating Procedure specifies the OD (optical density) at the laser wavelength(s) being used. The OD specified is the minimum OD sufficient to protect the user against a momentary intrabeam or specular reflection exposure. Contact the LSO for any questions you may have regarding laser protective eyewear.
- For **visible lasers**, the minimum OD required to protect the user against intrabeam viewing should allow the viewing of a diffuse spot on a light colored surface. If the laser protective eyewear has an OD much larger than the specified minimum OD, it may be impossible to properly view a diffuse beam spot (or even see properly in the laser facility).
- In some instances (visible lasers from 400 - 450 nm and 650 - 700 nm), it may be preferable to reduce the OD below the specified intrabeam minimum OD to better view a diffuse spot. Reducing the OD by 1 or 2 should substantially improve viewing while still offering adequate eye protection (the intrabeam OD has a X10 safety margin calculated into the value, which includes the human aversion (blink) response). Reducing the specified OD by a number greater than 2 may reduce the protection factor enough to allow eye injury should a specular reflection be viewed accidentally.

- For **invisible lasers**, the minimum OD for intrabeam viewing should not be reduced, as OD reduction will not aid in viewing the beam. Instead, the laser protective eyewear should be chosen to allow the wavelength produced by the viewing aid to be transmitted while absorbing the invisible beam. Luminous transmission for protective eyewear that is designed specifically for UV and IR wavelengths is often good. For example, a Nd:YAG beam at 1064 nm is being aligned with the use of an IR sensing card, which absorbs some of the 1064 nm radiation and emits radiation at 550 nm. The calculated intrabeam OD for the Nd:YAG is 6.0. A good choice for laser protective eyewear would be a goggle with a UVEX type 06 filter (an OD of 8+ at 1064 nm and an OD of less than 1 at 400 to 700 nm). This goggle has a visible light transmission of 70% and should allow the diffuse spot to be easily viewed while giving excellent protection from the invisible Nd:YAG beam. **NOTE**: This eyewear would obviously not be a good choice if the Nd:YAG beam frequency was doubled to 532 nm.
- All laser protective eyewear should have a luminous transmission sufficient to allow safe operation in the laser facility. The luminous transmission should be about 35%. Laser protective eyewear with a low luminous transmission will generally not be worn by users and so cannot provide any protection. A proposed European Standard CEN sets full protection VLT eyewear level at 20%, and 40% for alignment eyewear. One way to accommodate this would be to increase illumination in the workplace.

CARE AND MAINTENANCE

The proper care and maintenance is essential to ensure that the equipment remains in good condition and is serviceable. Eyewear can represent a significant investment. It will last longer and give better service if it is kept clean and properly stored. Poorly maintained eyewear will not only need to be replaced more often but can be a liability to the wearer.

Storage: Eyewear should be stored in clean and sanitary “ready for use” condition in an area away from dust and dirt and other contaminants. The eyewear should also be kept in an area away from exposure to chemicals and vapors, which could degrade or affect the material over time. This may be especially true in some of the plastic lenses in that the organic dyes used as absorbers are more readily affected by heat and/or ultraviolet radiation, which cause the filter to significantly darken. In addition to affecting the eyewear, contaminants in the work area may also be introduced into or around the eye when the contaminated eyewear is worn.

Cleaning: If the eyewear needs to be cleaned, follow the recommendations of the manufacturer. Generally, a mild soap solution is fine for polycarbonate eyewear. Special care may need to be taken for coated or laminated eyewear.

Inspection: This shall include inspection of the filter material **for pitting, crazing, cracking,** and inspection of the goggle frame for mechanical integrity and light leaks. Straps should be inspected as well and replaced if they have been stretched or are frayed.

Subject Area: ***Laser Safety***

Guidance on Interlock Systems for Lasers

Effective Date:**Jan 23, 2015**

The Laser Safety Subject Area requires that Class 4 lasers have their controlled areas interlocked. The Electrical Safety Subject Area details the requirements for technical design, hardware, testing, and documentation for these systems. As guidance from ES&H for design basis requirements, the level of protection category for Class 4 laser systems is for "critical" hazards and the design probability for their failure is considered "remote."

The Electrical Safety Subject Area provides the minimum requirements for noncommercial interlock systems, which were installed for personnel protection at the Laboratory after January 1995. In addition, any modifications to a preexisting system must be designed to maximize compliance with this Standard. For those systems predating January 1995, the new documentation and testing requirements apply. The required documentation will give a reviewer a brief summary of what systems are in place and how they are tested. For your guidance, the following are required:

1. A written functional description of the interlock system, which includes

a. Hazards that are to be controlled by interlock protection;
b. Means by which the interlock provides protection;
c. Entry and search protocols if applicable, including announcements, alarms and emergency responses;
d. Response of the system in normal operation, and to fault conditions and foreseeable personnel error, as well as to equipment failure.

2. Documentation of the physical and electrical configuration of the system, including circuit diagrams, wiring diagrams, and component specifications.

3. Written test procedures that specify test frequency (at least every six months) and completeness, including prepared checklists to ensure complete functional and auditable records of tests of the system.

4. A description of configuration management for controlling design, modifications, replacements, and maintaining complete and accurate documentation.

The following exhibits are provided to illustrate the implementation of interlocks in laser systems at Brookhaven National Laboratory (BNL). The exhibit Laser Lab Interlock Instrumentation Test Procedure is an interlock inspection checklist that illustrates the level of detail required, even for a comparatively simple interlock system. Interlock systems serve an important protection function.

The only official copy of this file is the one on-line in SBMS.

Before using a printed copy, verify that it is the most current version by checking the *effective date*.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Guidelines for Laser Pointer Safety

Effective Date:**Jan 23, 2015**

These guidelines cover the use of all Class 2 or Class 3A/R laser pointers used for seminar or classroom presentations. The use of any other class laser pointer will need the prior approval of the Laser Safety Officer.

Rationale:
The use of laser pointers as an instructional aid has been gaining increased popularity. Laser pointers fall into two laser hazard classifications. One is Class 2, for which the human blink reflex is sufficient to provide protection; power output is less than 1 mW. The other is Class 3A/R, which can be safe for momentary viewing, but a recognized eye hazard, if viewed through optics. The Class 3A/R power output is between 1-5 mW. Most of the laser pointers available are Class 3A/R, in the 630-680 nm range.

Labeling of Pointers:
Potential users should be aware that some of these devices might also lack the appropriate warning labels. Federal law, 21 CFR 1040 requires the laser pointer manufacturer, to have a laser-warning label on the pointer. The label needs to show the laser hazard symbol, laser classification, laser wavelength, and maximum power output. The laser pointer should not be used if it is missing this label.

Green Pointers:
A new group of laser pointers is on the market, frequency doubled Nd:YAG lasers, whose output may be either continuous or pulsed. The output beam is 532 nm, with a blocked infrared beam at 1064 nm. These pointers are exceptionally bright to the human eye, and for safety, it is critical that the invisible 1064-nm beam-blocking filter be in place.

Laser Pointer Safety Guidelines

When used as intended, these devices do not present a hazard to the user or members of the audience. The following guidelines are provided to maximize safety:

- Use only those pointers labeled as Class 2 or 3A/R.
- Never intentionally stare into the laser beam.
- Never intentionally aim the pointer beam at oneself or another person, particularly in the facial area.
- The beam should always be directed away from the audience.
- The beam should be turned off when not in use.
- Mirror-like surfaces should be avoided when directing the laser beam. A reflected beam can act like a direct beam on the eye.

Emergencies:
Although the potential for injury from a laser pointer is very slight, notify your supervisor and get medical attention, if an eye injury from laser use is suspected. Call the Laboratory's emergency extension 2222, or 911.

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Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Hazards Associated with Using Lasers

Effective Date:**Jan 23, 2015**

Electrical Hazards

The most lethal hazard associated with lasers is the high voltage electrical systems required to power lasers. Several deaths have occurred when persons working with high voltage sections of laser systems did not follow commonly accepted safety practices. All equipment must be installed in accordance with the National Electrical Code (NEC). Electrical Safety training may also be required (see the Electrical Safety Subject Area) as well as Lockout/Tagout training (see the Lockout/Tagout [LOTO] Subject Area), if there is a need to work on power supplies. CPR training is required where potential exposure to lethal high voltage equipment exists.

Electrical Safety Guidelines

1. Do not wear rings, watches, or other metallic apparel when working with electrical equipment.
2. Do not handle electrical equipment when hands or feet are wet or when standing on a wet floor.
3. When working with high voltages, regard all floors as conductive and grounded.
4. Be familiar with electrocution rescue procedures and emergency first aid.
5. Before working on electrical equipment, de-energize the power source. Lock and tag the disconnect switch.
6. Check that each capacitor is discharged, shorted and grounded before working in the area of the capacitors.
7. Use shock preventing shields, power supply enclosures, and shielded leads in all experimental or temporary high-voltage circuits.

Chemical Hazards

Many dyes used as lasing medium are toxic, carcinogenic, corrosive, or pose a fire hazard. The laser dye itself is generally present in low concentrations (typically 10-2 to 10-5 molar). The toxicity information is pretty scant although the MSDS will supply appropriate information pertaining to the toxicity, personal protective equipment, and storage of chemicals.

Decomposition products, aerosols, gases, or vapors can be produced by laser-target interactions or exhausted by lasers. Proper ventilation is required to reduce the exposure levels of the products or exhausts below standard exposure limits.

Cryogens have a large expansion ratio as they warm up to “room” temperature. A liquid liter of a cryogen may expand to several hundred times its liquid volume, as it becomes a gas, displacing some of the air as it expands. An oxygen deficient atmosphere is considered to be one that contains < 19.5% oxygen. Hydrogen is a flammable cryogen and poses a special danger because

of its wide flammable range (about 7-84%) in air. Liquid oxygen, while not flammable per se, can enhance combustion in the area where it is present. An oxygen-enhanced atmosphere is one that contains ? 23.5% oxygen. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic material. Cryogens can also cause burns to the eyes and skin; care must be taken when dispensing these liquids. Always use the appropriate protective clothing, face shields, and gloves.

Compressed gases used in lasers present serious health and safety hazards. In and of themselves, they represent stored energy and may be otherwise hazardous or toxic (such as with the halogens for excimers). Problems may arise when working with unsecured cylinders, cylinders of hazardous materials not maintained in ventilated enclosures, and gases of different categories (toxins, corrosives, flammable, oxidizers) stored together.

Collateral radiation

Radiation other than that associated with the primary laser beam is called collateral radiation. Examples are X-rays, ultraviolet (UV), plasma, and radio frequency emissions.

Ionizing Radiation

X-rays could be produced from two main sources in the laser laboratories. One source is high-voltage vacuum tubes of laser power supplies, such as rectifiers, and thyratrons, and the other is electric-discharge lasers. Any power supplies, which require more than about 10 keV, may produce X-rays.

UV and Visible

Laser discharge tubes and pump lamps may generate UV and visible radiation. The levels produced may exceed the Maximum Permissible Exposure (MPE) and thus, cause skin and eye damage.

Plasma emissions interactions between very high power laser beams and target materials may in some instances produce plasmas. The plasma generated may contain hazardous UV and visible emissions.

Radio Frequency (RF)

Q switches and plasma tubes are RF excited components. Unshielded components may generate radio frequency fields that exceed federal guidelines.

Fire Hazards

Class 4 lasers can represent a fire hazard. Depending on construction material, beam enclosures, barriers, stops and wiring are all potentially flammable if exposed to high beam irradiance for more than a few seconds.

Laser -Generated Air Contaminants (LGACs)

Chemical materials, either as intended or accidental targets of lasers, can readily convert into toxic gases or aerosols by oxidation, vaporization, or thermal decomposition, and result in laser-generated air contaminants (LGACs). The quantity, composition, and chemical complexity of the LGAC depend greatly upon the beam irradiance. Examples include formation of ozone from

ultraviolet (? < 240 nm) radiation, vaporization of firebrick made with beryllium, decomposition of plastic, which can form hydrochloric acid, hydrofluoric acid, phosgene, and hydrogen cyanide. When the target irradiance reaches a given threshold, approximately 10E7 W/cm², target materials including plastics, composites, metals, and tissues, may liberate toxic and noxious airborne contaminants. The amount of the LGAC may be greater for lasers that have most of their energy absorbed at the surface of the material. Such compounds may be gaseous or particulate and can, under certain conditions, pose occupational concern. In addition, special optical materials used for far infrared windows and lenses have been the source of potentially hazardous levels of airborne contaminants. For example, calcium telluride and zinc telluride will burn in the presence of oxygen when beam irradiance limits are exceeded. Exposure to cadmium oxide, tellurium, and tellurium hexafluoride should also be controlled. While it is difficult to predict what LGAC may be released in any given interactive situation, it is know that contaminants, including new compounds, can be produced with many types of lasers.

Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitors may explode violently if they fail during operation. These components are to be enclosed in a housing, which will withstand the maximum explosive force that may be produced. Explosive failure of capacitors is normally preceded by a leakage of stored current between the dielectrics and evidenced by a degradation of system pulses. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Consequently, care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.

Noise

Noise hazards are sometimes associated with laser operation, especially when firing some very high-power pulsed lasers. This noise is often associated with the discharge of capacitor banks. Permissible levels vary depending on the magnitude and number of pulses. The impulse noise may exceed permissible levels. If noise overexposure is suspected, contact the Safety and Health Services Division to request an investigation by a qualified Noise and Hearing Conservation professional.

The only official copy of this file is the one on-line in SBMS.

Before using a printed copy, verify that it is the most current version by checking the *effective date*.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Instrumentation Ti-Sapp Operation

Effective Date:**Jan 23, 2015**

Instrumentation Ti:Sapp Operation is provided as a Word file.

Instrumentation Ti:Sapp Operation

Standard Operating Procedures
Laser system: Ti:sapphire laser oscillator and amplifier.

A. Laser Oscillator

Laser specification - oscillator

Pump laser: Class 4, diode-pumped solid-state laser, 7 Watt, cw, 532 nm.
Output: Class 4, mode-locked Ti:sapphire solid-state laser, 400 mW, 100 MHz, 800 nm, 100 fs.

Laser system configuration - oscillator

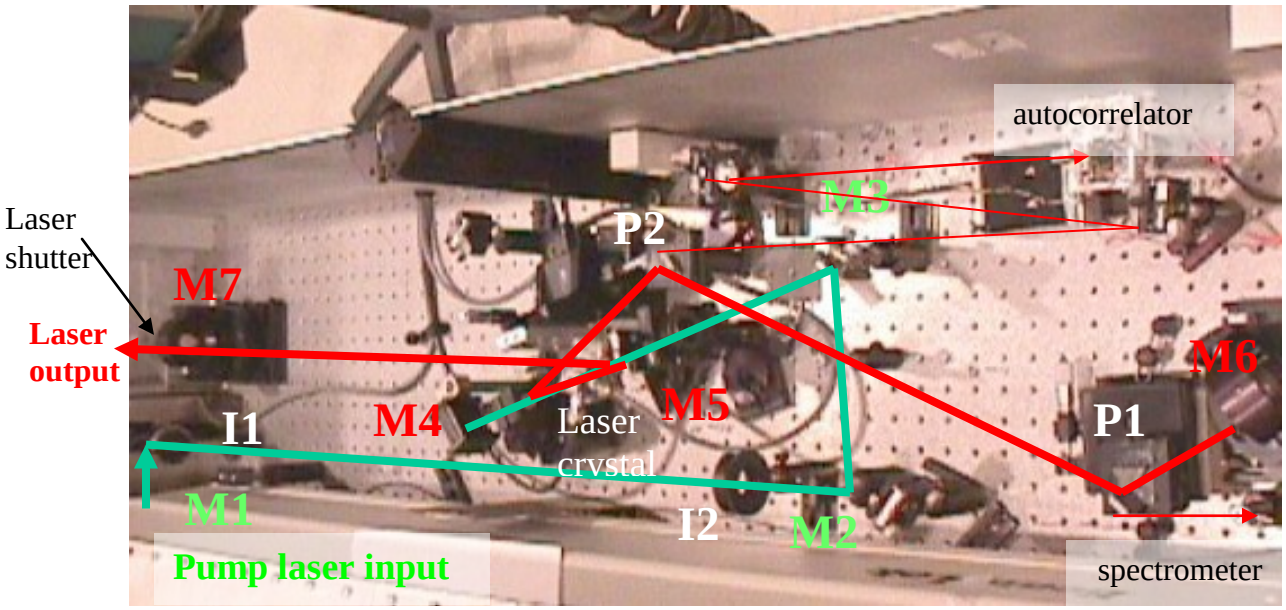


Figure 1. Ti:sapphire laser oscillator

Laser operation - oscillator

The system consisting of the Argon ion pump laser and the Ti:sapphire laser oscillator, is fully enclosed in a metal case. The oscillator consists of an argon ion pump laser and a passive Ti:sapphire laser cavity. A manual flip panel from the top of the enclosure is available for alignment and routine laser start up of the laser oscillator. A laser shutter indicated in Figure 1 normally blocks the laser output. Laser shutter is in fail-safe mode - in the close position on power fail condition. Upon uncontrolled entrance to the laser controlled area, interlock will break and the laser shutter will close to block the output.

The laser oscillator operation procedures are:

1. Wear correct laser safety goggle.
2. Ensure the flip panel of the laser enclosure is completely closed.
3. Enable the Ti:sapphire oscillator on the laser selection switch box, laser controlled area is interlocked.

4. Turn Argon laser on – enable main power supply of the argon ion laser, turn the water circulation on, and enable the argon ion laser from the control panel of the power supply.
5. After laser warm-up (~45 minutes), mode-lock the Ti:sapphire laser by manually flipping open the top laser enclosure, and translating the prism, P1 in Figure 1.
6. Close the top flip panel.
7. The mode-locked operation is monitored by the spectrometer and/or the autocorrelator outputs displayed on the computer monitor.

The laser oscillator is ready for experiments.

Laser alignment – oscillator

Laser oscillator beam alignment is *not* a routine operation. It should only be done by qualified and trained laser operators.

The procedures for the normal laser alignment are:

1. Wear correct laser safety laser goggle. No beam should be viewed directly.
2. Ensure the laser-controlled area is secured and interlocked.
3. Place an optical power meter at the output aperture
4. Lower the power of the argon ion pump laser to below 10 mW
5. Flip open the top panel of the laser enclosure.
6. Send the pump beam through the iris I1 and I2 by manipulating mirror M1.
7. Send the pump beam through mirror M5 to the laser crystal by manipulating mirrors M2 and M3. The pump beam path can be observed with the laser safety goggle using a green fluorescence card.
8. Increase the pump power to the normal operating power of 4 Watt.
9. With the aid of an IR fluorescence card, send the laser fluorescence from mirror M4 to prisms P2 and P1. Using mirror M6 to retroreflect the dispersed fluorescence light back to the laser crystal.
10. With the aid of an IR fluorescence card, send the laser fluorescence from mirror M5 to the output coupler M7. Then retroreflect the fluorescence light from M7 back to the laser crystal.
11. The oscillator cavity should be lasing and NIR optical power should be registered on the power meter.

The laser oscillator cavity alignment is done.

Laser service – oscillator

The only service on the oscillator is the argon ion pump laser. Servicing and replacing the argon ion tube are done by the manufacturer. Optics in the argon ion laser cavity is occasionally cleaned. Follow the cleaning procedures detailed in the manual of the argon ion laser.

B. Laser Amplifier

Laser specification - amplifier

Pump laser: Class 4, diode-pumped solid-state Nd:YLF laser, 6 mJ/pulse, max PRF 1 kHz, 532 nm.
Output: Class 4, 1 mJ/pulse, 1 kHz, 800 nm, 200 fs.

Laser system configuration - amplifier

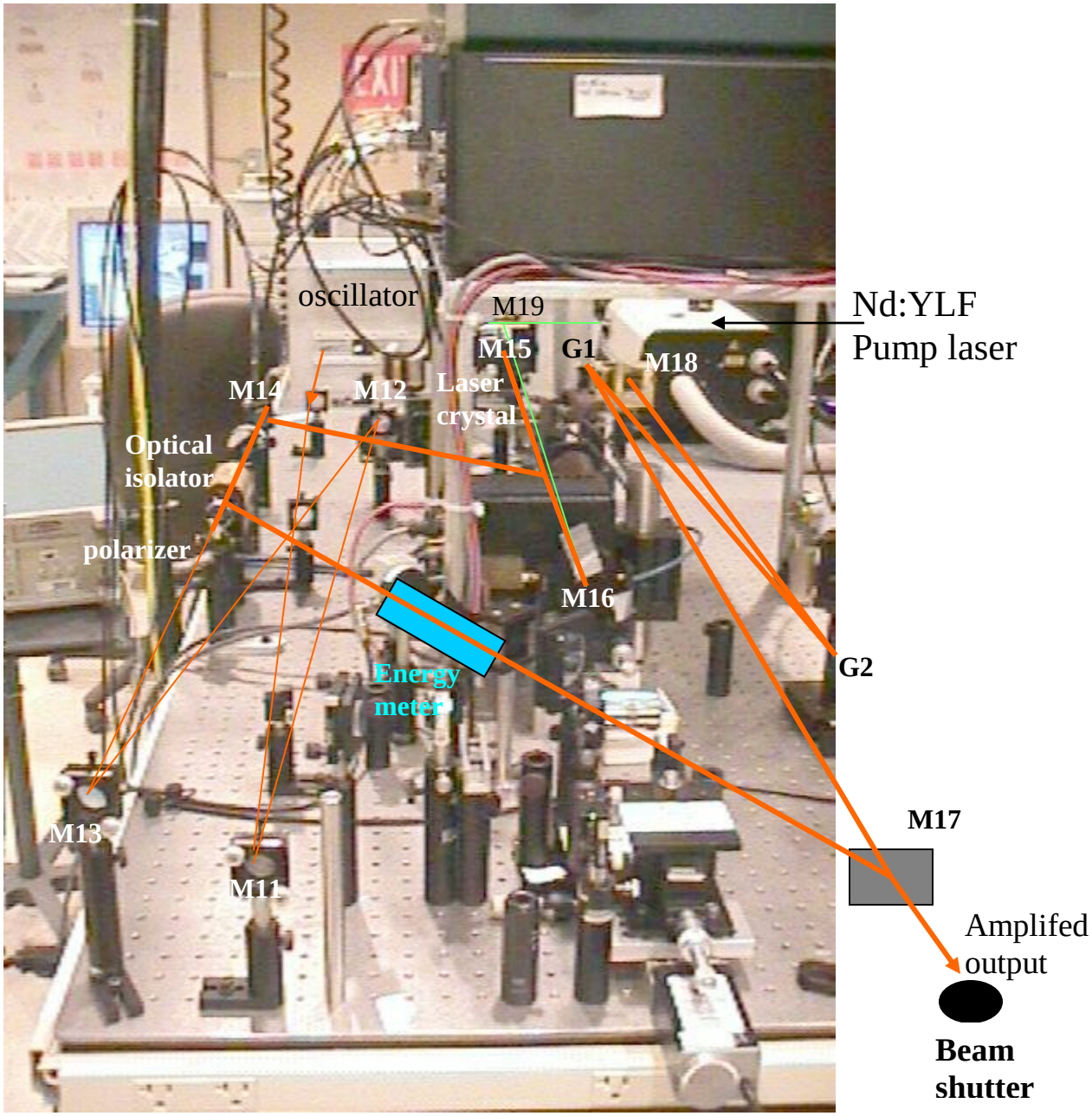


Figure 2 – Ti:sapphire laser amplifier

Laser operation - amplifier

The complete amplifier system, Nd:YLF pump laser and the Ti:sapphire regen amplifier, pulse stretcher, and pulse compressor, are (will be) completely enclosed in a metal enclosure. A manually flip panel from the top of the enclosure is available for alignment and routine laser start up of the laser amplifier. A laser shutter, indicated in Figure 2, normally blocks the light output. Laser shutter is in power fail-safe mode--in the close position on power fail condition. Upon uncontrolled entrance to the laser controlled area, interlock will break, the pump laser power will be deactivated by an intra-cavity shutter internal to the Nd:YLF laser, simultaneously, the beam shutter to the amplified Ti:sapphire laser is also closed.

The laser amplifier operation procedures are:

1. Wear correct laser safety goggle.
2. Ensure the flip panel of the laser enclosure is completely closed.
3. Enable Ti:sapphire amplifier on the laser selection switch box, laser controlled area is interlocked.
4. Flip open the top panel and place a calibrated energy meter at the output of the amplifier to monitor the optical power.
5. Open the manual aperture on the oscillator enclosure to allow the propagation of the stretched seed beam to the regen amplifier.
6. Turn Nd:YLF pump laser on – enable the close-cycle chiller unit and then enable the Nd:YLF laser when the temperature readout of the chiller dropped below 20 degrees C.
7. After laser warm-up (~45 minutes), turn on the Pockels cell to switch out the amplified pulse.
8. Remove the energy meter and close the top panel.

The laser amplifier is ready for experiments.

Laser alignment – amplifier

Laser amplifier beam alignment is *not* a routine operation. It should only be done by qualified and trained laser operators.

The procedures for the normal laser alignment are:

1. Wear correct laser safety laser goggle. No beam should be viewed directly.
2. Ensure the laser-controlled area is secured and interlocked.
3. Flip open the top panel of the laser enclosure.
4. Lower the energy of the Nd:YLF pump laser to below 0.1 mJ/pulse at 100 Hz repetition rate.
5. Redirect the pump beam to the laser crystal through mirror M15 by manipulating mirror M19.
9. Remove the quarter-wave plate in the amplifier beam cavity.
10. Increase the energy of pump beam to about 4 mJ/pulse.
11. With the aid of an IR fluorescence card and an infrared viewfinder, locate the florescence of the laser crystal and send the fluorescence light from mirrors M15 and M16 back to the laser crystal.
12. A self-lasing beam will be emitted from the regen amplifier to mirror M14, through the optical isolator and the polarizer to the output beam aperture.
6. Place an optical energy meter at the desired position to monitor the amplified output energy.
13. Open the manual aperture of the oscillator enclosure to allow the propagation of the stretched seed beam to the regen amplifier.
7. Insert the quarter-wave plate in the amplifier beam cavity.

8. Enable the Pockels cell to switch out the amplified pulse. The energy meter should read the correct amplified pulse energy.

The laser amplifier alignment is done.

Laser service – amplifier

The only service on the amplifier is the Nd:YLF pump laser. The manufacturer does servicing and replacing the pump laser diode. Optics of the amplifier are routinely cleaned using optical cleaning solutions when no lasers are energized.

C. Optical Beam Transport

The safety goggles provide primary protection to the user in the vicinity of the laser, and hence appropriate goggles should be worn at all times. Never view a laser beam directly. The alignment procedures applied to all classes of lasers, including Class 4.

1. Prior to transport an optical beam to an experimental setup, plan a lay out of the transport and the procedure to be followed to implement the transport.
2. Identify locations that could cause stray reflections or scattering from elements such as lens, windows or any other reflective surface.
3. A Class 2/3A alignment laser shall be used to establish the desired optical beam transport path and to locate the position of the desired optics. The beam path should be established by placing two or more iris along the beam path.
4. Block any scattered beams. Set up equipment, such as fluorescent card, camera, and energy/power meter to view the target indirectly.
5. Reduce the power/energy of the desired optical beam to be transported to below the maximum permissible optical power/energy of the goggles recommended for that laser.
6. Align the desired optical beam to the alignment beam path using the already positioned alignment iris. Align the optical beam to be collinear with the alignment laser.
7. View the alignment to the target indirectly to confirm the alignment.
8. The beam transport is done. Confirm the scattered beams are blocked at various locations.

The beam transport line is ready to transport the full beam intensity of the desired optical beam to the target.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Instrumentation YAG Operation

Effective Date:**Jan 23, 2015**

Instrumentation YAG Operation is provided as a Word file.

INSTRUMENTATION YAG OPERATION

Nd: YAG Q Switching Dye Maintenance Procedure

Avoid contact with the skin at all times. Wear Neoprene or latex gloves whenever handling laser dyes. Work under the exhaust hood whenever handling this solvent.

I. Daily maintenance

1) The stability of the oscillator should be checked each day. If stability decreases, the most likely cause is the dye.

a) see start-up procedure for dye maintenance indications;
b) close shutter before adding dye;
c) add small amount of dye.

NOTE: Dye is kept in a dry box in the lab refrigerator. The dye should receive minimum light. The dye reservoir should be kept about ~ full. When adding concentrated dye to the reservoir, the dye should be brought to room temperature before removing the stopper from the bottle to avoid contamination due to water condensation.

d) allow the dye to circulate at least 1 minute;
e) open shutter and recheck the stability.

II. Bi-weekly maintenance: complete dye change

1) Turn pump off.
2) Drain tubes into small beaker; drain and clean the dye reservoir completely. Circulate
3) Dichloroethane through system for 1 minute.
4) Discard.this solvent, drain the tubes, clean the reservoir again.
5) Repeat steps 1-4 until the solvent runs completely clear.
6) Turn on the laser; it should lase with solvent only.
7) Allow the laser to run for 1 ~ hours with clear solvent.
8) Empty this solvent from the system and replace with new.
9) Add about 6 cc of dye concentrate to the dye cell. (The method for preparing this concentrate is given in part III of this document.)
10) While viewing the individual train of pulses on the scope, continue to add small (1 cc) amounts of dye concentrate until 9-10 pulses per train are obtained.
11) Allow the dye to circulate overnight in this condition.
12) In the morning, adjust the dye concentration to obtain 7 pulses and adjust the optics to produce stable operation.

III. Making dye concentrate

1) Use whole bottle of dye (l00 mg Exciton Q Switching 5)

NOTE: Exposed dye powder degrades quickly.

NOTE: Solvent reacts unfavorably with plastic. When working with solvent, make sure not to use bottles with plastic covers.

2) In a clean bottle, mix dye with 150 m1 of 1, 2 Dichloroethane. Shake dye and solvent until completely mixed. Use the magnetic stirrer.
3) Using tweezers, get one circular filter from blue filter box (10 micron filter).
4) Place the filter into its holder and place holder into large flask with pump. The holder is constructed in such a way that the filter fits between a reservoir at the top and a funnel at the bottom.
5) Place dye concentrate into reservoir before the filter so that the dye flows through the filter. Turn on the pump. The pump should be run for only 1-2 seconds, or until the concentrate is completely pulled through the filter.
6) Repeat this process several times.
7) Place filtered dye into clean flask and place this flask into the refrigerator dry box. After about 15 minutes, close the bottle with a stopper.

Management System: ***Worker Safety and Health***

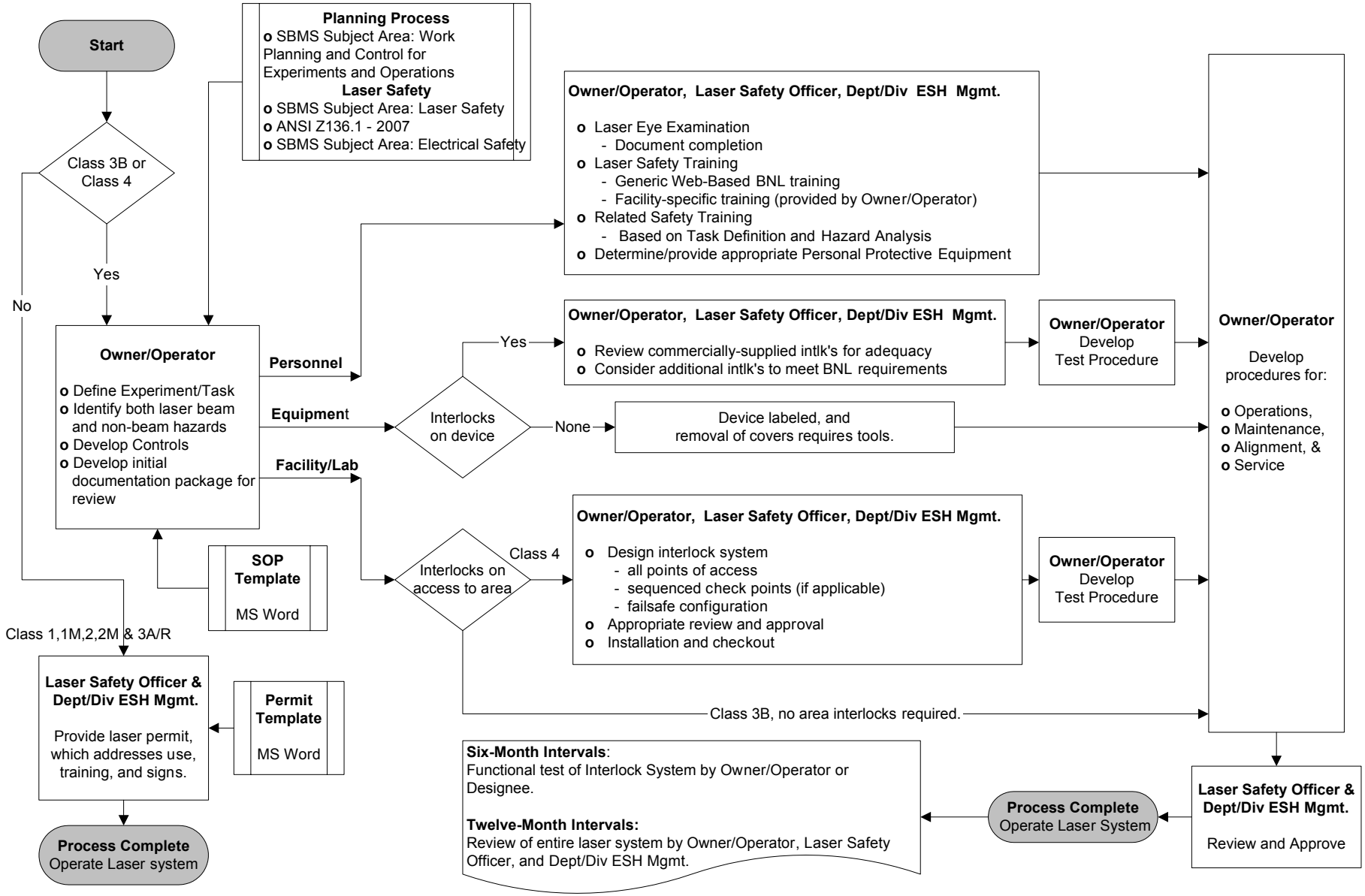
Subject Area: ***Laser Safety***

Laser Commissioning Process Flowchart

Effective Date:**Jan 23, 2015**

The Laser Commissioning Process Flowchart is provided as a PDF file.

Laser Commissioning Process Flowchart



Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser Electron Accelerator Facility (LEAF) Working Procedures

Effective Date:**Jan 23, 2015**

Laser-Electron Accelerator Facility (LEAF) Working Procedures is provided as a Word file.

Laser-Electron Accelerator Facility (LEAF)
Working Procedures

Administrative Controls Description:

General comments for all work in Laser-Electron Accelerator Facility (LEAF) Laser Controlled Areas (LCAs).

1. All lasers under this Standard Operating Procedure (SOP) are operated in the LCAs at LEAF described above. Appropriate warning signs are posted at each entrance. All lasers have mandated labels. Flashing warning signs, activated whenever the interlock system is live, are mounted outside the main laser room entrances. Yellow warning lights are lit at the doors to the vault when its interlock system is active.

2. Remember that Class 4 laser beams are dangerous to view even in diffuse reflection. Class 4 limits and maximum permissible exposures (MPEs) for all wavelengths emitted by lasers covered by this SOP are listed in the section "Analyze the Laser System Hazards" above, and eyewear requirements are listed in the eyewear table below. Requirements for when/what eyewear is required are discussed below.

3. Before working within the laser nominal hazard zones at LEAF, users must remove personal objects that might intercept a beam accidentally during work. This is especially true for shiny BNL badges attached to ropes around your neck or even clipped to shirts, and things like rings and watches when making laser adjustments. Such objects make very good reflectors that could cause specularly reflected beams to leave the NHZ in an uncontrolled fashion.

4. Users must use good sense in avoiding actions that place themselves or co-workers at risk of laser-related injuries. Users must be aware of others in the LCA, especially those who enter the area while work is in progress.

5. If at any time a user is unsure of the correct procedure to follow, the user shall **STOP** and seek the advice of the responsible Principal Investigator (PI).

6. Definitions:
    a. Operation – use of laser systems; will involve energy adjustments via waveplate/polarizer pairs already in place.
    b. Gross alignment – any procedure where beams are not already on optical components, or those that may lead to beams leaving established paths and optical surfaces.
    c. Simple/normal alignment – procedures where beams do not leave established beam paths/optical surfaces/beam stops.

Operation SOP:

1. Except during alignment procedures, all primary and specular beams, as well as diffuse reflections from Class 3B and 4 beams must be contained on the laser tables using non-combustible diffusely reflecting or absorbing laser beam stops that do not create hazardous vapors. Class 3B and 4 beams between tables across open floor space must be enclosed in protective tubes. All optics must be solidly attached to laser tables so that accidental "bumps" cannot send beams in unknown directions. Physical protection must be provided from vertical beams or any other situation where unexpected exposure might occur. Under these conditions, the nominal hazard zone is confined to the areas above the laser tables, and eye protection as specified below is required for work within the nominal hazard zone. *Any light outside the NHZ must be at levels at or below the maximum permissible exposure (MPE).*

2. Lasers should be operated at the minimum intensity consistent with experimental requirements.

3. Nd:YAG lasers must be used with enclosed termination of all unused harmonics.

4. Users must know and follow the routine operation instructions for all lasers as described in the manuals provided by the laser vendors.

5. A common operation procedure is the adjustment of the amplifier pump energy, by rotating wave plates in the amplifier box. While this does not involve moving any beams, users must:
    a. Wear eye protection for 800 nm (532 nm is optional; if worn, users must know ahead of time where the beams are to avoid skin burns).
    b. Do not put any objects (fingers, watches, cards) in any beams.
    c. Only open the amplifier cover as much as necessary, and close the covers when done.

6. Another common procedure is measuring the output energy of the amplifier and it's third harmonic:
    a. Wear eye protection for invisible beams including both 800 nm and 266 nm.
    b. Do not put any objects (fingers, watches, cards) in any beams.

Alignment SOP:

1. There must be no intentional intrabeam viewing with the eye!!

2. Maintain good housekeeping practices on laser tables; keep the area where you will be working clear of excess objects that might scatter a beam unpredictably, and keep combustible materials away from Class 4 hazards.

3. Consider the use of low power Class 1 to 3A coaxial CW alignment lasers when convenient.

4. During alignment procedures, only persons immediately involved in the procedure are to be in the LCA. These individuals must have appropriate training and be listed in this document as authorized laser users.

5. When it is possible that hazardous beams are not completely contained on the laser tables, the room must be posted with a temporary alignment warning sign on the door warning those that may enter not to until the procedures are completed and the sign removed.

6. During all times the possibility for inadvertent exposure to laser light exists, appropriate laser safety eyewear must be worn. The appropriate ratings are listed in the PPE section and discussed further below.

7. Definite termination of the beam path must be in place before the beam is allowed to propagate. Use moveable beam stops to ensure that uncontrolled propagation does not occur.

8. Alignment procedures are always to be performed with the minimum practical laser power levels and repetition rates. This is especially true for the output of the primary pump lasers. In the case of the Quanta-Ray Nd:YAG lasers this can be achieved by the use of long pulse mode that dramatically reduces the high-energy 532 nm output, and produces a much longer pulse width. Since you must be able to see this beam in order to align it, refer to the comments in #14 below. The beam energy can be further reduced if necessary by tweaking the harmonic generator off the maximum, though you should be aware that this will also move the beam some. Inside the TSA amplifier, use the wave plates to minimize the 532 nm energy to the point (nearly minimum) where a good quality beam is just visible before doing alignments.

9. Following a new laser beam set-up or change in alignment, a survey of the (ANSI) Limited Open Beam Path will be conducted to verify that all unwanted beams and reflections have been properly terminated. Opaque barriers will be used to confine low intensity stray reflections and scattered light to the optical tables. Any unwanted primary or specular beams in excess of Class 4 thresholds will be terminated in a beam stop within the NHZ that does not produce hazardous diffuse reflections.

10. Gross alignment of beams from Class 4 lasers into experiments or tunable lasers should be done with beams attenuated as far below Class 4 thresholds as possible, with eye protection adequate for the beam in use.

11. Routine laser-specific alignment procedures may be simple or complex. In either case, specific procedures are outlined in the operation and alignment manuals supplied by the manufacturers, and they must be followed.

12. Pre-position optical components during gross alignment as best as possible and bolt them down before allowing beams to propagate.

13. Be aware of the potential for errant reflections (stray beams) from and leaked beams transmitted through components such as polarizers and dielectric mirrors. For example, do not use or rotate calcite polarizers with escape windows without first being sure that all exit beams will be blocked. Check for stray beams at each step and again after completing all alignment steps.

14. In some circumstances, unobstructed viewing of diffuse reflections from Class 3B beams is non-hazardous as long as reasonable care is taken. In cases where it is necessary to view diffuse reflections from Class 3B laser beams in order to align them, the following apply:
    a. Heightened awareness of beam hazards is necessary during such procedures. Special care and planning is needed to insure that unexpected specular reflections do not occur, and that hazards from other beam sources are controlled.
    b. Consider other ways first that do not require direct viewing of diffuse reflections (viewers, emissive cards).
    c. Use the minimum possible energy consistent with the task at hand.
    d. Discuss new procedures with a colleague in order to identify safe methods.
    e. Use only cards without shiny surfaces to produce only diffuse reflections.
    f. Minimize viewing time of the beam on a card; often only a second or two is necessary to align a beam.
    g. Do not put your face close to the source of diffuse reflections; use cards at arm's length away when possible.
    h. Consult the eyewear PPE table below for ODs need for diffuse reflections of the primary laser sources, and the discussion below it on how to limit the hazard to below the MPE by using primarily lower power, distance from the source, and viewing time.

i. If you are not absolutely sure about the safety of the procedure you are doing, stop and seek assistance from the appropriate PI and/or other reference person such as the department LSC or BNL LSO.

Maintenance SOP:

1. Laser users will conduct some routine maintenance. This includes procedures such as replacement of the flash lamps and cooling water in the Nd:YAG lasers, optics cleaning and/or replacements in all lasers. All of these procedures are to be conducted in strict accordance with the methods described in the laser manuals provided by the manufacturers, and only by individuals with appropriate training who are listed in this document. Any maintenance on BNL constructed equipment will only be performed under the direction of the appropriate PI.

2. Non-routine maintenance and troubleshooting is a serious matter, as injury or damage to equipment could result from actions taken in unfamiliar circumstances. When an uncharacterized fault condition exists, some actions that would be safe under ordinary conditions may have unsuspected hazards. Diagnostic work on optics or electronics will thus only be undertaken strictly following specific instructions in the manufacturer's laser manual, or in consultation with the manufacturer's service engineering staff. When there is any uncertainty about the safety of a diagnostic procedure, don't do it, and seek additional expert guidance. The laser manufacturer's field service engineers may be required to perform specialized maintenance tasks for which lab employees lack specific expertise and training.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser Lab Interlock Instrumentation Test Procedure

Effective Date:**Jan 23, 2015**

The Laser Lab Interlock Instrumentation Test Procedure is provided on this page and as a Word file.

Scope: The following procedure is for checking the operation of the laser interlock system. The interlock system is located in Building 535, Room B-102A.

The interlock system is to be tested bi-annually as per the Electrical Safety Subject Area.

Procedure:

A. Setting up the interlock system in preparation for testing.

1. Ensure that all laser systems are off.
2. Close all doors to the laser lab.
3. Ensure that all of the laser enable switches on the interlock panel are in the off position.
4. Move the warm-up/operate switch to the “warm-up” position.
5. Check that all laser shutters are closed.
6. Check that the “LASER ON” warning light, located above the door at the main entrance of the laser lab, is off.
7. Check that the two yellow “SHUTTER OPEN” warning lights, located on both sides of the main entrance door, are off.

B. Testing each laser system. **Note:** Do not use the door pass-through system. It will be tested separately in section C of this procedure.

1. Choose one laser system and attempt to start it. It should *not* start. **Note:** The term “start” means that the electronics for the laser system will turn on but there is an external interlock fault condition.
2. At the interlock system panel flip the switch that enables that laser.
3. Check that the “LASER ON” warning light is *on*.
4. Check that the yellow “SHUTTER OPEN” warning lights are still *off*.
5. Reattempt to start the same laser. It *should* start. **Note:** The laser system’s external interlock clears.
6. Move the warm-up/operate switch to the “operate” position. The shutter for the laser under test should open. If not, press the reset button. The “SHUTTER OPEN” warning light should turn *on*.
7. Open any door. The shutter should close and the “SHUTTER OPEN” warning light should turn *off*.
8. Open and close the door several times. The shutter should remain closed and the “SHUTTER OPEN” warning light should remain *off*.
9. Repeat steps 6 through 8 for the other two doors.

10. Repeat steps 1 through 9 for all laser systems. Check off each laser system on the Interlock Check Log after testing.
11. Turn off electrical power to all lasers.

C. Testing the door pass through systems. **Note:** This section does not require any laser system to be energized.

1. Enable any one of the laser systems and open its shutter. The “SHUTTER OPEN” warning light should turn on.
2. Press the door pass through button. The yellow light on the pass-through enclosure should turn *on*. The buzzer should sound.
3. Open the door. The shutter should remain open and the “SHUTTER OPEN” warning light should remain *on*.
4. Close the door and press the pass-through button again.
    a. The yellow light on the pass-through enclosure should turn *off*.
    b. The buzzer should stop sounding.
    c. The shutter should remain open.
    d. The “SHUTTER OPEN” warning light should remain *on*.
5. Press the pass-through button and exit the laser lab through the doorway. Close the door behind you. Press the pass-through button.

    a. The yellow light on the pass-through enclosure should turn *off*.
    b. The buzzer should stop sounding.
    c. The “SHUTTER OPEN” warning light should remain *on*.
6. Press the pass-through button. The yellow light on the pass-through enclosure should turn *on*.

    a. Enter the laser lab through the doorway. Close the door behind you. Press the pass-through button. The yellow light on the pass-through enclosure should turn *off*.
    b. The buzzer should stop sounding.
    c. The shutter should remain open.
    d. The “SHUTTER OPEN” warning light should remain *on*.
7. Press the pass through button. Time how long the pass-through system takes to reset itself. It should be less than 30 seconds.

D. Returning the interlock system to service.

1. Flip the warm-up/operate switch to the “warm-up” position.
    a. The laser shutter should close.
    b. The “SHUTTER OPEN” warning light should turn *off*.
2. Flip all laser enable switches to the off position. **Note:** The “LASER ON” warning light should turn *off*.
3. Ensure that all laser systems are *off*.
4. Open any door.

E. Test complete. **Note:** Be sure to initial and date the Interlock Check Log.

The only official copy of this file is the one on-line in SBMS.

Before using a printed copy, verify that it is the most current version by checking the *effective date*.

Laser Lab Interlock Instrumentation Test Procedure

Scope: The following procedure is for checking the operation of the laser interlock system. The interlock system is located in Building 535, Room B-102A.

The interlock system is to be tested bi-annually as per the Electrical Safety Subject Area**.**

Procedure:

A. Setting up the interlock system in preparation for testing.

1. Ensure that all laser systems are off.
2. Close all doors to the laser lab.
3. Ensure that all of the laser enable switches on the interlock panel are in the off position.
4. Move the warm-up/operate switch to the "warm-up" position.
5. Check that all laser shutters are closed.
6. Check that the "LASER ON" warning light, located above the door at the main entrance of the laser lab, is off.
7. Check that the two yellow "SHUTTER OPEN" warning lights, located on both sides of the main entrance door, are off.

B. Testing each laser system. **Note:** Do not use the door pass-through system. It will be tested separately in section C of this procedure.

1. Choose one laser system and attempt to start it. It should *not* start.
   - Note: The term "start" means that the electronics for the laser system will turn on but there is an external interlock fault condition.
2. At the interlock system panel flip the switch that enables that laser.
3. Check that the "LASER ON" warning light is *on*.
4. Check that the yellow "SHUTTER OPEN" warning lights are still *off*.
5. Reattempt to start the same laser. It *should* start.
   - The laser system's external interlock clears.
6. Move the warm-up/operate switch to the "operate" position. The shutter for the laser under test should open. If not, press the reset button. The "SHUTTER OPEN" warning light should turn *on*.
7. Open any door. The shutter should close and the "SHUTTER OPEN" warning light should turn *off*.
8. Open and close the door several times. The shutter should remain closed and the "SHUTTER OPEN" warning light should remain *off*.
9. Repeat steps 6 through 8 for the other two doors.
10. Repeat steps 1 through 9 for all laser systems. Check off each laser system on the Interlock Check Log after testing.
11. Turn off electrical power to all lasers.

C. Testing the door pass through systems. **Note:** This section does not require any laser system to be energized.

1. Enable any one of the laser systems and open it's shutter. The "SHUTTER OPEN" warning light should turn *on.*
2. Press the door pass through button. The yellow light on the pass-through enclosure should turn *on*. The buzzer should sound.
3. Open the door. The shutter should remain open and the "SHUTTER OPEN" warning light should remain *on*.
4. Close the door and press the pass-through button again.
    - The yellow light on the pass-through enclosure should turn *off.*
    - The buzzer should stop sounding.
    - The shutter should remain open.
    - The "SHUTTER OPEN" warning light should remain *on.*
5. Press the pass-through button and exit the laser lab through the doorway. Close the door behind you. Press the pass-through button.
    - The yellow light on the pass-through enclosure should turn *off.*
    - The buzzer should stop sounding.
    - The "SHUTTER OPEN" warning light should remain *on.*
6. Press the pass-through button. The yellow light on the pass-through enclosure should turn *on.*
    - Enter the laser lab through the doorway. Close the door behind you. Press the pass-through button. The yellow light on the pass-through enclosure should turn *off.*
    - The buzzer should stop sounding.
    - The shutter should remain open.
    - The "SHUTTER OPEN" warning light should remain *on.*
7. Press the pass through button. Time how long the pass-through system takes to reset itself. It should be less than 30 seconds.

D. Returning the interlock system to service.

1. Flip the warm-up/operate switch to the "warm-up" position.
    - The laser shutter should close.
    - The "SHUTTER OPEN" warning light should turn *off.*
2. Flip all laser enable switches to the off position.
    - The "LASER ON" warning light should turn *off.*
3. Ensure that all laser systems are off.
4. Open any door.

E. Test complete.

Be sure to initial and date the Interlock Check Log.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser Safety Instructions (BNL Chemistry Example)

Effective Date:**Jan 23, 2015**

Laser Safety Inspection (BNL Chemistry Example) is provided as a PDF file.

LASER SAFETY INSPECTION (BNL) CHEMISTRY EXAMPLE
Chemistry Department Semiannual Laser Safety Inspection Protocol

1. Chemistry Department LSIs shall be carried out two times per calendar year. The first shall be performed in the month of January, the second in the month of July.
2. LSIs shall be performed by the Chemistry Department LSC or delegate as approved by the Chemistry Department Chair.
3. LSIs shall be made of all laser laboratories located in the Chemistry Department (Building 555). A laser laboratory shall be defined as any laboratory for which a BNL SOP has been authorized.
4. At least one owner/operator named in the SOP must be present during the inspection.
5. During December and June, reminders shall be sent to each owner/operator stating that LSIs will be scheduled and that laser safety door interlock system tests be performed and documented prior to the LSI.
6. The LSI shall consist of: (1) confirmation that all laser-specific documentation, including SOPs, laser registrations, interlock tests, and laser-specific training forms, are current, (2) inspection of the lab and (3) discussion of any changes made in documentation, operations, personnel, and equipment since the preceding LSI. A *Semiannual Laser Safety Inspection and Action Item Checklist* specifying all required inspection items shall be developed and maintained by the LSC.
7. During and immediately following the LSI, a *Semiannual Laser Safety Inspection and Action Item Checklist* shall be completed for each laser laboratory. The checklist shall document where the laboratory documentation, experimental configuration, or operations are found to be noncompliant, and shall indicate corrective actions. Completed checklists shall be kept on file by the LSC.
8. In cases where a corrective or other action is required, a copy of the inspection checklist shall be given to the owner/operator. It shall be the responsibility of the owner/operator to: (1) confirm that the specified action(s) is(are) completed, (2) sign and date the checklist and (3) return the checklist to the LSC within two weeks of the inspection date. Failure of the owner/operator to return the completed checklist may result in the issue of a Stop Work order.
9. Upon completion of the LSIs, the LSC shall file a report with the Chemistry Department Chair and Chemistry Department ES&H Coordinator. This report shall consist of a completed *Semiannual Chemistry Department Laser Safety Inspections Report* form and shall document that the inspections have been performed. In the event that non-compliance has been noted, a memo documenting any comments and concerns to the Chair and ES&H Coordinator shall also be included. The semiannual reports must be filed on or before the 15th day of February and August.
10. Following completion of the July LSI report, SOPs shall be reviewed. The LSC shall initiate the review process by sending the current electronic copy of each SOP to the responsible owner/operator. An updated version of the SOP shall be returned to the LSC within three weeks. The LSC will forward the updated SOPs to the LSO for review. Subsequently, the LSC shall convene meetings, attended by the LSO, the owner/operator, and the LSC, for the purpose of finalizing and authorizing the SOPs.

Acronyms:

BNL	Brookhaven National Laboratory	LSO	Laser Safety Officer
ES&H	Environmental Safety and Health	LSI	Laser Safety Inspection
LCA	Laser Controlled Area	SOP	Standard Operating Procedure
LSC	Laser Safety Coordinator		

Semiannual Laser Safety Inspection and Action Item Checklist

Room No.:		**SOP Control No.:**		
Owner/Operator:	*Print Name*	*Signature*	**Date:**	
Inspector:	*Print Name*	*Signature*	**Date:**	

A	***P***	***Item***	***Required corrective or other action(s)***
Administrative Controls			
		SOP authorizations current	
		Correct door signage in place	
Laser Inventory			
		SOP consistent with active inventory	
		New laser arrived or expected	
Personnel Authorizations			
		Web laser training current for all	
		Laser specific training current for all	
		SOP personnel list current	
		New users arrived or expected	
Door Interlock System			
		All active lasers interlocked	
		Logbook current	
Engineering Controls			
		Enclosures & barriers adequate	
		All beams properly terminated	
		Recent changes in NHZ / beam path	
		Recent changes in experimental geometry	
Personal Protection Equipment			
		Eyewear adequate and accessible	
		PPE for New lasers available	
Other			
		Power supply cabinets closed	
		Excimer laser ventilation	

A *= Action required,* ***P*** *= Passed (No action required); If corrective or other action is required, owner/operator shall confirm that specified action is completed, sign and date below, and return this form within two weeks to the Chemistry Department Laser Safety Coordinator.*

This space reserved for additional comments from the inspector and/or feedback from the owner/operator

I certify that the above specified actions have been completed.

Print Name	*Signature*	Date

Semiannual Chemistry Department Laser Safety Inspections Report

Assessment Description: Building 555 Semiannual Laser Safety Inspection Report	
Scope of Assessment: Interlock logs (six-month interlock checks carried out – system in compliance for next 3 months) Laser SOPs (annual updates, signatures of all personnel, verification against active lasers in room) Laser Registration Records (all lasers in room properly registered).	
Conducted by: Laser Safety Coordinator N. Camillone (or delegate as approved by Chemistry Chair)	**Date:**
Persons contacted: At least one laser user/owner in each laser room to verify documentation/laser use for room.	
Procedures or documents reviewed: Interlock Logs, Laser SOPs, Laser Registration Records, Lab inspected	

Room Number	Document	Comments	Date
22 Wishart/Cook	Interlock Test SOP Registration	._____. ._____.	
115 Creutz	No Interlock No SOP Registration (2 class 2 lasers)	._____. ._____.	
121 DiMauro	Interlock Test SOP Registration	._____. ._____.	
127 White/Beuhler	Interlock Test SOP Registration	._____. ._____.	
221 Hahn	No interlock (3A rules apply) SOP Registration	._____. ._____.	
261 Fujita	Interlock Test SOP Registration	._____. ._____.	
306 Hall/Suits	Interlock Test SOP Registration	._____. ._____.	
321 Preses	Interlock Test SOP Registration	._____. ._____.	
323 Fockenberg	Interlock Test SOP Registration	._____. ._____.	
325/327 Hall/Sears	Interlock Test SOP Registration	._____. ._____.	
329 Suits	Interlock Test SOP Registration	._____. ._____.	
353 Camillone	Interlock Test SOP Registration	._____. ._____.	

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

BNL General Laser Registration Form

Effective Date:**Jan 23, 2015**

The BNL General Laser Registration Form is provided as a Word file. It is used to notify the Laser Safety Officer of any changes in disposition of lasers at the Laboratory including

1. Registration of new lasers.
2. Change in location of lasers.
3. Transfer of ownership of lasers.

Multiple lasers may be listed on a single form, however, please use a separate form for each type of disposition change. Some types of lasers are exempted from registration requirements at BNL including laser pointers and lasers built into equipment such as CD writers or laser printers. Guidelines for safe laser pointer use are provided in the exhibit Guidelines for Laser Pointer Safety. If you are in doubt about the need for registration of a laser system, contact the Laser Safety Officer.

BNL GENERAL LASER REGISTRATION FORM

Instructions: Fill out form and submit to the Laser Safety Officer (LSO). The LSO sends back the signed form and the owner/operator retains the original.

This form may be used to change the disposition of any laser requiring registration at Brookhaven National Laboratory (BNL). The form can be used for multiple lasers, but should only represent one type of change of disposition. Please indicate the type of change (check one option):

1. **Register new laser(s)** ☐
2. **Document the movement of lasers to new locations** ☐
3. **Document the transfer of ownership of laser(s)** ☐

LASER INFORMATION

Laser Type (lasing medium)		Manufacturer/Model/Serial # BNL Bar Code (if applicable)	Class	Wavelength(s)	Maximum power/PRF*	Beam Diameter (cm)
1						
2						
3						
4						
5						
6						

***PRF:** Pulse Repetition Frequency

PRIMARY LOCATIONS OF LASERS

Building	Room #

LASER OWNER/OPERATOR: _____ **DEPT**: _____

(For transfer only) ☐
(FROM) LASER OWNER/OPERATOR: _____ **DEPT**: _____
(TO) LASER OWNER/OPERATOR: _____ **DEPT**: _____

Project:

Comments:

LSO: _____

Record Number (Assigned by LSO) LR_____

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

BNL Low Power Laser Use Permit

Effective Date:**Jan 23, 2015**

The BNL Low Power Laser Use Permit is provided as a Word file. When completed, it documents the controls for utilization of a Class 1M, 2/2M, or 3A/R laser outside of a laser controlled area in a specific location where lasers are not normally used. The form may not be used for operation of higher class lasers (3B and 4), which require the development and approval of a Laser Controlled Area Standard Operating Procedure. Some types of lasers are exempted from permit requirements at BNL including laser pointers and lasers built into equipment such as CD writers or laser printers. Guidelines for safe laser pointer use are provided in the exhibit Guidelines for Laser Pointer Safety. If you are in doubt about requirements for use permits for a laser system, contact the Laser Safety Officer.

BNL LOW POWER LASER USE PERMIT FORM

This permit is to be filled out to document controls for the utilization of Class 1M, 2/2M, and 3A/R lasers outside of Laser Controlled Areas in a specific location(s) where lasers are not normally used.

Instructions: Fill out the form and submit it to the Laser Safety Officer (LSO) for approval and signature. The LSO sends back the signed form and the owner/operator retains the original.

PERIOD OF OPERATION: **FROM** _____ **TO** _____
(Period not to exceed one year)

PURPOSE and USE LOCATION(s):

LASER OWNER/OPERATOR: _____ **DEPT**: _____

SAFE USE GUIDANCE (Laser Safety Officer):

1. NEVER point or aim a laser of any power at anybody.
2. Operate lasers with beam horizontal, above, or below eye level.
3. Remove unnecessary reflectant surfaces from near the beam path.
4. Use a beam stop at the end of its useful path.
5. NEVER view a laser beam using an optical instrument (such as binoculars, microscope) unless the Laser Safety Officer has technically approved the procedure.
6. Always use LOWEST power rating practical. The Laser Safety Officer may have a Class 2 laser available for use on loan, which may satisfy the purpose.
7. The area of use is required to be POSTED with an appropriate sign to be supplied by the Laser Safety Officer.
8. Lasers of identical or lower power may be substituted for use.

Required Controls and Comments:

APPROVAL (LSO): _____ **DATE**: _____

Record Number (Assigned by LSO) LP _____

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser Controlled Area Standard Operating Procedure (SOP)

Effective Date:**Jan 23, 2015**

The Laser Controlled Area Standard Operating Procedure (SOP) Template, Laser Controlled Area SOP Template with Annotations, and Commentary on the Laser Controlled Area SOP have been provided as Word files. The Worksheet Exhibit Crosswalk (PDF file) is provided as guidance to assist in developing the required documentation.

Commentary on the Laser Controlled Area SOP

Laser Controlled Area SOP Template

Laser Controlled Area SOP Template with Annotations

Worksheet Exhibit Crosswalk

Commentary on the Laser Controlled Area Standard Operating Procedure (SOP)
Brookhaven National Laboratory (BNL) Laser Safety Committee

What's in a name?

The term Standard Operating Procedure or SOP is a reserved descriptor included in the ANSI standard on Safe Use of Lasers (ANSI Z136.1-2000 Sec 4.4 'Administrative and Procedural Controls [Class 3b and Class 4] *et seq.*). The standard defines an SOP as a "Formal written description of the safety and administrative procedures to be followed in performing a specific task." The use of the word 'Procedures' in this context is unfortunate, because it has lead to confusion in the implementation of SOPs at the Laboratory where procedures have their own cultural and contextual meaning.

The functions described for SOPs in the ANSI standard are more akin to Operational Safety Envelopes in the DOE oversight environment. Within the Laboratory, procedures for actually conducting work are developed through work planning or experimental review processes. BNL has chosen to adopt the ANSI standard for its implementation of a laser safety program and has retained the term SOP in the Laser Safety Program Subject Area as a way to help in facilitating implementation of the standard.

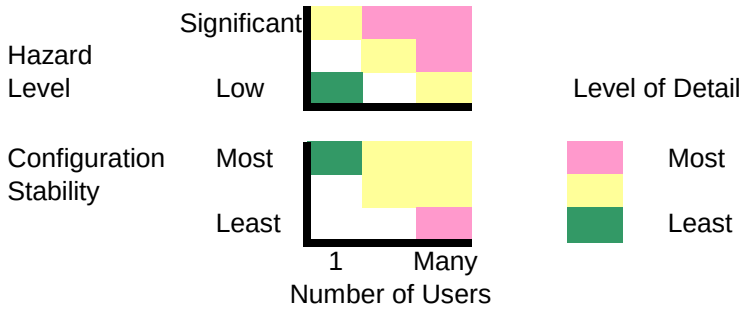
What is in a Laser Controlled Area SOP document at BNL?

In implementing the standard, as with other activities at BNL a graded approach is adopted. This allows the document to be tailored to the hazard levels and control measures that are suitable for a particular installation. At a minimum, the SOP must contain the information that allows for the identification of the hazard envelope for a particular laser installation and the control measures required to maintain a particular type of operation within the defined safety envelope. Additional information may be included as deemed necessary or convenient by either the installation owner or the Laser Safety Officer.

The SOP stands on a thorough analysis of the hazards and controls; hence it is a revision-controlled document where changes in the document should reflect real changes in the operational safety envelope. For this reason, information relating to details of particular set-ups that have no role in determining the safety envelope, but which might be subject to frequent changes, are best included in working procedures maintained through work planning or experimental safety reviews at the Department/Division level. The BNL Laser Controlled Area Standard Operating Procedure (SOP) Template is a useful guide to the types of information typically included in an SOP. It is important to note that SOPs must be reviewed *annually*.

The level of detail actually provided will be influenced by many factors including complexity, stability, and number of users of a system. This is illustrated qualitatively in the following figure:

Qualitative Guide for Graded approach to SOP Content



The level of detail included should be sufficient to allow a knowledgeable individual to verify that the laser controlled area is configured as described, and that the required control measures are in place.

The ANSI standard outlines three modes of operation for laser controlled areas; Operation, Maintenance, and Service. They each describe expected types of operations, which must be anticipated in the hazard analysis. Operation envisions the 'normal use' of a laser installation. In the standard, Maintenance is more narrowly defined than the usual meaning and describes activities meant to be performed by the trained user to ensure optimal operation of the laser for its intended function (including alignments). Service is a broader term that encompasses any kind of work on the laser system, which can include major repairs as well as adjustments necessary to keep the laser functional. In commercial systems, a service representative from the vendor would often perform this service.

The Art in Writing the SOP

SOPs must cover all three modes of operation (where applicable). Practice at BNL allows for separate documents describing one or more of these modes where the separation provides better clarity in understanding the safety envelope.

In the conduct of research, the Principal Investigator needs to ensure that all aspects of safety are understood by, and communicated to, the users of systems under their charge. Safety procedures can and should be a vital part of this process.

Establishing the Envelope

In describing the working boundaries for operation/maintenance/service, the writer should mentally walk through the steps of the task to be accomplished, stopping and noting where specific steps/precautions need to be taken to conduct the work safety. Any of these steps or precautions, which are important for safety, needs to appear in the SOP. These steps needn't necessarily be listed chronologically or step-wise, as they would be encountered in a checklist format. The writer may choose to list them in terms of the magnitude of the hazard they represent. This latter approach may work well especially

for relatively simple systems. Whatever form they take, the SOP should highlight and outline what is necessary.

Laser manuals

Laser manuals supplied by the manufacturer can be useful and should be consulted in composing procedures for operation, and maintenance including internal alignment, of the laser itself. Of course, because the manuals typically refer to laser specific issues, they cannot be relied upon to address beam hazards once the beam exits the aperture. What happens after the beam leaves the laser proper also needs to be addressed.

SOPs as training tools

Specific training is required to be given to all laser users by the person responsible for the laser system they will be using. In constructing the SOP, the information they provide should be viewed as complementing the operations specific training and should also serve as a summary of safety highlights for each system. Some basic level of knowledge needs to be assumed, however; they should be written for those individuals who are least familiar with the system. Writing them at this level also prompts the writer to analyze and think about how the work should be done. Writing them at a higher level may cause people to omit information that may be obvious to the author, but could be of vital safety consequence to the uninitiated user. Writing the SOP at the introductory level will also facilitate the addition of less experienced users to the laboratory.

The SOPs are also a useful tool for reinforcing safety expectations, especially to new or non-BNL employees. It is also important to maintain frequent contact between the worker and the supervisor and a clear definition of the expectations of conduct for both. Both scientific staff supervisors and the people under their charge can benefit from sharing work experiences through regular discussions with their staff. In some settings this may be best accomplished through regularly scheduled meetings, even if they are informal.

Revisions to SOP's

The question inevitably arises; what will trigger a revision of an SOP? The broad answer is anything that changes the safety envelope of the laser controlled area. This in turn depends on examining the proposed changes in activity. For example, if an SOP specified a laser of a specific model from a particular vendor, a change in the laser would trigger a revision. If in the same situation, the laser was specified in the SOP with all of the parameters required to perform a hazard analysis, perhaps even giving the envisioned laser model information as a reference, substitution of a laser of substantially the same or reduced hazard characteristics need not trigger a revision. In such cases advice should be sought from the Laser Safety Officer.

BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system(s) listed below. All American National Standard Institute (ANSI) Hazard Class 3B and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed *annually*. Modify the template for this document to fit your particular circumstance.

System description:
Location:

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator(s) for this laser is/are listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:		
Name:	*Signature:*	*Date:*

AUTHORIZATION

Work with all ANSI Class 3B and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required. Additional signatures, e.g., the ALSO, are to be added to this signature block when necessary.

BNL LSO (printed name)	*Signature*	*Date*
Department ES&H Coordinator (printed name)	*Signature*	*Date*
Department Chair/Division Manager (printed name)	*Signature*	*Date*

APPLICABLE LASER OPERATIONS
☐ Operation ☐ Maintenance ☐ Service ☐ Specific Operation (specify)

RELATIONSHIP TO OTHER DOCUMENTS

Specifically name other documents, (such as ESRs, SADs/SARs, other SOPs) that describe hazards present in the Laser Controlled Area outside the scope of this document.

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls. Laser system characteristics necessary for eyewear calculations and NHZ analysis are described along with the results in the PPE section of this document.

LASER SYSTEM CHARACTERISTICS						
Laser Type *(Argon, CO_2, etc.)*	Wavelength(s) (nm)	ANSI Class	Maximum Power or Energy/Pulse (W or J)	Pulse Length (s)	Repe-tition Rate (Hz)	Beam Diameter (mm)

Applicable Laser Operations:
Describe the scope of the work to be done, and how the laser system is used. Provide information regarding unusual circumstances necessary for evaluation of hazards by the LSO not provided elsewhere in this document (e.g., laser beams entering other equipment such as vacuum chambers and microscopes or propagated into unexpected places/directions).

Laser System Configuration:
Describe the laser beam path for fixed components of the system, and provide a functional/block diagram for complicated beam paths. Photographs may be used where they convey sufficient information. Note that Engineering Controls are described in a separate section below.

Identify hazards mitigated or created by the placement, movement, and/or status of components. Examples include any protective housings, beam stops, beam enclosures, and any critical optics (mirrors or lenses that could misdirect the beam and result in personnel hazard).

For specific *laser-related* hazards below, provide details (types, quantities, use) as appropriate. Details of non-laser related hazards should be cross-referenced to the other documents cited above.:

☐ **Cryogen Use**

e.g., laser cooling

☐ **Chemicals & Compressed Gases**

e.g., laser dyes, solvents, excimer laser gases

☐ **Electrical Hazards**

Describe circumstances that could lead to exposure to electrical hazards.

☐ **Other Special Equipment**

Equipment used with the laser[s] that may introduce additional hazards, e.g., beam viewers.

DESCRIBE CONTROLS

Recognition, evaluation, and control of laser hazards are governed by the following documents:

American National Standards Institute (ANSI) Standard for Safe Use of Lasers (ANSI Z136.1-2007)

BNL SBMS Subject Areas:

Laser Safety Subject Area
Electrical Safety Subject Area (section Interlock Safety for Protection of Personnel)

ENGINEERING CONTROLS

☐ Beam Enclosures	☐ Protective Housing Interlocks	☐ Other
☐ Beam Stop or Attenuator	☐ Key Controls	
☐ Activation Warning System	☐ Other Interlocks	
☐ Ventilation	☐ Emission Delay	

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review by the LSO/ALSO and the LESO, a copy of the design review documentation and written testing protocol must be on file. Completed periodic interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

ADMINISTRATIVE CONTROLS

☐ Laser Controlled Area ☐ Signs ☐ Labels ☐ Operating Limits

Class 3B and 4 lasers are required to be operated in Laser Controlled areas with appropriate warning signs and labels. The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer. All lasers must have a standard label at least indicating the system's wavelength and power. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Describe administrative operational limits (e.g., requirements to operate at reduced power) if appropriate.

Standard Operating Procedures (SOPs) are required for Class 3B and Class 4 laser system operation, maintenance/servicing and laser alignment. The SOPs need only contain the safety information necessary to perform these tasks and identify appropriate control measures including postings (showing required ODs for eyewear and ANSI hazard class) and any additional personal protective equipment required. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Operation:

Describe controls for routine use and adjustments of laser system(s).

Maintenance/Service:

Describe additional controls required to maintain laser operation. May or may not require beam access. Follow manufacturer instructions where appropriate. Routine maintenance: replacing consumables (flashlamps, gases, dyes, etc.). Non-routine service: Less frequent: Replacing damaged components, diagnostics, etc.

Outside service personnel:

Indicate how outside service personnel are trained and supervised. Work performed by outside service personnel is planned according to the Work Planning and Control for Experiments and Operations Subject Area and regulated by the Guest and Visitors Subject Area.

Alignment:

As most laser accidents occur during alignment, provide a description of routine procedures where appropriate and controls to mitigate the hazards. For non-routine procedures, provide a safety envelope necessary to protect workers. This includes activities such as initial system/ experimental alignment.

Laser system configuration changes:

Changes to the laser system can result in new concerns about safety or damage to equipment. Describe how changes are communicated between coworkers (e.g., lab notebooks, logs, whiteboards).

PERSONAL PROTECTIVE EQUIPMENT

Skin Protection: If the potential exists for damaging skin exposure as determined by the LSO (particularly for UV lasers 295-400 nm or welding/cutting applications), describe the hazard(s) and the method(s) used for mitigation. Skin-covers and/or sunscreen creams are recommended.

Eyewear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Eyewear must be routinely checked for cleanliness and lens surface damage. Disinfection of shared eyewear should be considered; if the eyewear needs to be cleaned, follow the recommendations of the manufacturer. Generally, a mild soap solution is fine for polycarbonate eyewear. Special care may need to be taken for coated or laminated eyewear.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the circumstances and the precautions that will be taken to prevent eye injury.

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

Most accidents occur during alignment. Extra care must be taken during alignment. Eyewear must be worn during alignment, but it must be remembered that eyewear is NOT the first level of laser safety. Eyewear protects the wearer only when all other safety procedures and equipment have failed. Better protection is provided by careful consideration of procedures and proper beam management.

LASER SYSTEM CHARACTERISTICS						
Laser Type (Argon, CO_2, etc.)	Wavelength(s) (nm)	ANSI Class	Maximum Power or Energy/Pulse (J or W)	Pulse Length (s)	Repe-tition Rate (Hz)	Beam Diameter (mm)

EYEWEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***

EYEWEAR SPECIFICATIONS		
Laser System Eyewear Identification***	Wavelengths	Optical Density

*Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to ensure that they can identify and control the risks presented by the laser systems they use. Owners/Operators must receive a baseline medical surveillance eye examination, documented in the Occupational Medicine Clinic before using lasers. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL online training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.,
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

All laser safety training must be repeated every two years.

BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

This document defines the safety management program for the laser system(s) listed below. All American National Standard Institute (ANSI) Hazard Class 3B and 4 laser systems must be documented, reviewed, and approved through use of this form. Each system must be reviewed *annually*. Modify the template for this document to fit your particular circumstance.

System description:
Location:

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator(s) for this laser is/are listed below. The Owner/Operator is the Line Manager of the system and must ensure that work with this laser conforms to the guidance outlined in this form.

Owner/Operator:		
Name:	*Signature:*	*Date:*

AUTHORIZATION

Work with all ANSI Class 3B and 4 laser systems must be planned and documented with this form. Laser system operators must understand and conform to the guidelines contained in this document. This form must be completed, reviewed, and approved before laser operations begin. The following signatures are required. Additional signatures, e.g., the ALSO, are to be added to this signature block when necessary.

About this Form:
The template was created to help in the development of a Laser Controlled Area Standard Operating Procedure (LCA-SOP or SOP). As explained elsewhere, at BNL the SOP is treated as a safety envelope and information document. The template is a form that provides "blanks" for the information most typically required in creating an SOP document.

Using the Form:
The explanatory text in each field can either be left on the completed form or removed. It is really meant to be a narrative to help explain what kind of information is required. This annotated form is meant to provide elaboration beyond what is included in the word template.

System Description and Location: Couples the SOP to a particular installation.

Line Management Responsibilities: Assigns responsibility for the system to a accountable persons. The owner/operator(s) help(s) to develop the SOP, and has responsibility for assuring that the conditions it describes are met when the laser installation is in operation in any of the described modes.

Authorization: Demonstrates that the Laser Safety Officer (LSO) and cognizant Department Chair/Division Manager and ESH personnel have reviewed the LCA-SOP. The signature list is not frozen in stone. The entries are the minimum required signature, others can sign in addition if desired.

BNL LSO (printed name)	*Signature*	*Date*
Department ES&H Coordinator (printed name)	*Signature*	*Date*
Department Chair/Division Manager (printed name)	*Signature*	*Date*

APPLICABLE LASER OPERATIONS
☐ Operation ☐ Maintenance ☐ Service ☐ Specific Operation (specify)

RELATIONSHIP TO OTHER DOCUMENTS

Specifically name other documents (such as ESRs, SADs/SARs, other SOPs) that describe hazards present in the Laser Controlled Area outside the scope of this document.

LASER SYSTEM HAZARD ANALYSIS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system. The analysis includes both laser (light) and non-laser hazards. A Nominal Hazard Zone (NHZ) analysis must be completed to aid in the identification of appropriate controls. Laser system characteristics necessary for eyewear calculations and NHZ analysis are described along with the results in the PPE section of this document.

Applicable Laser Operations:
Can be used as a checkbox to show what kinds of operations this particular SOP describes. ANSI defines three, Operations, Maintenance (in which alignment is included) and Service, which is most often major repairs or installations often by the vendor. At BNL, other types of operation might be envisioned, hence the "Specific Operation" check box. In some cases sub-groups of uses or users may be applicable for a large facility laser. Where appropriate, check the box and enter the operation name or characteristics in the line below the boxes.

Laser System Hazard Analysis: The heart of the SOP. It lays out both the laser and non-laser hazards that one expects to encounter in the installation. It is important to enumerate all potentially hazardous coherent sources (including *e.g.*, frequency mixing or parametric sources) and their characteristics so that a full hazard analysis can be completed and the Nominal Hazard Zone, protective equipment needs, and required controls can be determined. The ANSI Standard has detailed procedures for determining laser class and NHZ, so these are best determined with the help of the LSO. Examples of typical non-beam hazards are given by the checkboxes. The laser system configuration helps both in identifying the hazards and later in the use of the SOP as an aid for field verification of the laser configuration it describes.

LASER SYSTEM CHARACTERISTICS						
Laser Type *(Argon, CO_2, etc.)*	Wavelength(s) (nm)	ANSI Class	Maximum Power or Energy/Pulse (W or J)	Pulse Length (s)	Repe-tition Rate (Hz)	Beam Diameter (mm)

Applicable Laser Operations:
Describe the scope of the work to be done, and how the laser system is used. Provide information regarding unusual circumstances necessary for evaluation of hazards by the LSO not provided elsewhere in this document (e.g., laser beams entering other equipment such as vacuum chambers & microscopes or propagated into unexpected places/directions).

Laser System Configuration:
Describe the laser beam path for fixed components of the system, and provide a functional/block diagram for complicated beam paths. Photographs may be used where they convey sufficient information. Note that Engineering Controls are described in a separate section below.

Identify hazards mitigated or created by the placement, movement, and/or status of components. Examples include any protective housings, beam stops, beam enclosures, and any critical optics (mirrors or lenses that could misdirect the beam and result in personnel hazard).

Laser System Hazard Analysis cont'd.

The "Laser System Characteristics" table comprises the input data for the laser safety calculations used to calculate hazards, required PPE and controls.

Different laboratories require different Laser System Configuration descriptions. For some laboratories, an annotated photograph may suffice. For other laboratories, a schematic diagram of the laser system and beam paths may be appropriate.

The reason for including the laser system configuration is to establish a safety envelope for operation. Don't include extraneous information that doesn't relate to safe operation of the laser.

For specific *laser-related* hazards below, provide details (types, quantities, use) as appropriate. Details of non-laser related hazards should be cross-referenced to the other documents cited above.:

☐ **Cryogen Use**

e.g., laser cooling

☐ **Chemicals & Compressed Gases**

e.g., laser dyes, solvents, excimer laser gases

☐ **Electrical Hazards**

Describe circumstances that could lead to exposure to electrical hazards.

☐ **Other Special Equipment**

Equipment used with the laser[s] that may introduce additional hazards, e.g., beam viewers.

DESCRIBE CONTROLS

Recognition, evaluation, and control of laser hazards are governed by the following documents:

American National Standards Institute (ANSI) Standard for Safe Use of Lasers (ANSI Z136.1-2007)

BNL SBMS Subject Areas:

Laser Safety Subject Area
Electrical Safety Subject Area (section Interlock Safety for Protection of Personnel)

Laser-related hazards: Don't reiterate non-laser related hazards like using large amounts of LN_2 for cooling a trap in a vacuum system. Hazards like that are covered in an ESR, so just cross-reference the ESR.

ENGINEERING CONTROLS

☐ Beam Enclosures ☐ Protective Housing Interlocks ☐ Other

☐ Beam Stop or Attenuator ☐ Key Controls

☐ Activation Warning System ☐ Other Interlocks

☐ Ventilation ☐ Emission Delay

Describe each of the controls in the space provided below this text. Interlocks and alarm systems must have a design review and must be operationally tested every six months. Controls incorporated by the laser manufacturer may be referenced in the manuals for these devices. **If any of the controls utilized in this installation requires a design review by the LSO/ALSO and the LESO, a copy of the design review documentation and written testing protocol must be on file. Completed periodic interlock testing checklists should be retained to document the testing history.**

Engineering Controls Description:

ADMINISTRATIVE CONTROLS

☐ Laser Controlled Area ☐ Signs ☐ Labels ☐ Operating Limits

Class 3B and 4 lasers are required to be operated in Laser Controlled areas with appropriate warning signs and labels. The format and wording of laser signs and labels are mandated by BNL and ANSI standards. Only the standard signs are acceptable. Standard signs are available from the BNL Laser Safety Officer. All lasers must have a standard label at least indicating the system's wavelength and power. Required labels must remain legible and attached. The manufacturer should label commercial systems.

Describe administrative operational limits (e.g., requirements to operate at reduced power) if appropriate.

Describe Controls: Having identified the hazards and the NHZ in the previous section, we now turn to dealing with the hazards through the application of appropriate controls. A brief list of applicable ES&H standards that most often apply to laser installations is given at left.

To the extent possible engineered controls are usually favored over administrative controls. A checkbox list to outline the engineered controls that apply is provided followed by space for information describing the control measures. Again the objective is the identification of the controls that are employed so they can be verified at the laser installation. Interlocks are often employed as a control measure. As noted at left, the section Interlock Safety for Protection of Personnel in the Electrical Safety Subject Area provides guidance on the requirements for design and testing of interlock systems.

The description provided should be sufficiently complete that a knowledgeable person can readily identify the control measures.

Administrative controls are usually used to provide identification of hazards, hazard boundaries, and operating limits. The LSO will assist in the identification of proper wording and content for signs that must be posted for laser-controlled areas.

Standard Operating Procedures (SOPs) are required for Class 3B and Class 4 laser system operation, maintenance/servicing and laser alignment. The SOPs need only contain the safety information necessary to perform these tasks and identify appropriate control measures including postings (showing required ODs for eyewear and ANSI hazard class) and any additional personal protective equipment required. The BNL Laser Safety Officer must approve SOPs and copies should be available at the laser installation for reference and field verification of stated control measures.

Operation:

Describe controls for routine use and adjustments of laser system(s).

Maintenance/Service:

Describe additional controls required to maintain laser operation. May or may not require beam access. Follow manufacturer instructions where appropriate. Routine maintenance: replacing consumables (flashlamps, gases, dyes, etc.). Non-routine service: Less frequent: Replacing damaged components, diagnostics, etc.

Outside service personnel:

Indicate how outside service personnel are trained and supervised. Work performed by outside service personnel is planned according to the Work Planning and Control for Experiments and Operations Subject Area and regulated by the Guest and Visitors Subject Area.

Alignment:

As most laser accidents occur during alignment, provide a description of routine procedures where appropriate and controls to mitigate the hazards. For non-routine procedures, provide a safety envelope necessary to protect workers. This includes activities such as initial system/experimental alignment.

Laser system configuration changes:

Changes to the laser system can result in new concerns about safety or damage to equipment. Describe how changes are communicated between coworkers (e.g., lab notebooks, logs, whiteboards).

(Controls cont'd)

Many of the accidents resulting in eye exposure occur during alignment or other activities not directly research. This type of work often requires a non-standard configuration of a relatively small number of components. It is important to identify these components and make sure that the hazards are well understood and appreciated by the system users.

PERSONAL PROTECTIVE EQUIPMENT

Skin Protection: If the potential exists for damaging skin exposure as determined by the LSO (particularly for UV lasers 295-400 nm or welding/cutting applications), describe the hazard(s) and the method(s) used for mitigation. Skin-covers and/or sunscreen creams are recommended.

Eyewear: All laser protective eyewear must be clearly labeled with the optical density and wavelength for which protection is afforded. Eyewear should be stored in a designated sanitary location. Eyewear must be routinely checked for cleanliness and lens surface damage.

1. For invisible beams, eye protection against the full beam must be worn at all times unless the beam is fully enclosed.
2. For visible beams, eye protection against the full beam must be worn at all times during gross beam alignment.
3. Where hazardous diffuse reflections are possible, eye protection with an adequate Optical Density for diffuse reflections must be worn within the nominal hazard zone at all times.
4. If you need to operate the laser without wearing eye protection against all wavelengths present, explain the circumstances and the precautions that will be taken to prevent eye injury.

Define eyewear optical density requirements by calculation or manufacturer reference and list other factors considered for eyewear selection. The BNL Laser Safety Officer will assist with any required calculations.

Most accidents occur during alignment. Extra care must be taken during alignment. Eyewear must be worn during alignment, but it must be remembered that eyewear is NOT the first level of laser safety. Eyewear protects the wearer only when all other safety procedures and equipment have failed. Better protection is provided by careful consideration of procedures and proper beam management.

Personal Protective Equipment:

This section identifies the equipment that is used to protect against inadvertent exposure when neither engineered nor administrative controls are deemed to be fully adequate protection. Usually this amounts to judicious selection of eyewear. One must be careful to identify the hazards, and select eyewear that provides adequate protection but does not unduly interfere with the planned work. Really dark shades with more than adequate OD that spend all their time on the table (instead of on your nose) because they are too dark to see through, are of absolutely no value. The annotation in the form provides further information regarding the proper use of laser eyewear. The required ODs are determined using the Laser System Characteristics and the calculation methods from the ANSI Laser Standard. The Laser System Characteristics are repeated here for convenience.

If you need to operate the laser without wearing eye protection you must describe the precautions that will be implemented to prevent eye injury.

To aid in the selection of eyewear, the SOP template provides a table to help identify the requirements for the eyewear, and a second table to list the specifications of eyewear actually selected for use.

LASER SYSTEM CHARACTERISTICS						
Laser Type (Argon, CO_2, etc.)	Wavelength(s) (nm)	ANSI Class	Maximum Power or Energy/Pulse (J or W)	Pulse Length (s)	Repe-tition Rate (Hz)	Beam Diameter (mm)

EYEWEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***

Tables:

The Laser System Characteristics are the input data for the eyewear requirements, as mentioned above. To do the calculations, the LSO needs all the information in the table, so complete information is essential.

The LSO can calculate the Nominal Hazard Zone using the methods in the ANSI Standard. However, the LSO has the discretion to simply declare the Laser Controlled Area the NHZ, and this frequently makes better sense than the calculation.

The LSO calculates the required OD for the eyewear. The laser owner/operator is responsible for picking appropriate eyewear that meets the requirements.

EYEWEAR SPECIFICATIONS		
Laser System Eyewear Identification***	Wavelengths	Optical Density

*Diffuse ODs are calculated assuming a 600 second exposure, a viewing distance of 20 cm, perfect reflectivity, and viewing normal to the surface. The ODs required can decrease for more typical conditions in the laboratory.

**The Nominal Hazard Zone is that zone or distance inside which exists a hazard to the eye from a diffuse reflection (as well as direct or specularly reflected light) for the time specified, in this case, 600 seconds (10 minutes).

***Specified eyewear may not be the only possible option, but represents an approved choice; depending on other laser hazards present in the lab, other eyewear may be acceptable provided the optical densities are equivalent or greater than those required.

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to ensure that they can identify and control the risks presented by the laser systems they use. Owners/Operators must receive a baseline medical surveillance eye examination, documented in the Occupational Medicine Clinic before using lasers. Owners/Operators and Qualified Laser Operators must complete the awareness level BNL online training course (TQ-LASER) every two years.

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training must be documented with a checklist that includes**

- Trainee name and signature
- Owner/Operator signature
- Date
- Brief list of topics covered e.g.,
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

Training:
This section outlines the training that all users (including owner/operators) must complete prior to operation of the laser systems identified in the SOP.

Documentation of qualified operators and their training status is no longer a part of the SOP. However, an up-to-date list of operators and the training they have received must be on file, and should be available at the laser installation. If an applicable SOP or other required training document is revised, the user training list becomes the resource for assuring that all qualified users are notified of the changes. It is also the vehicle for recording that they have received any updated training that is required. If appropriate, training of individuals for specific tasks should be noted in the training documents.

Note that all laser safety training must be repeated every two years (at a minimum).

Guidance or Reference	Forms	Exhibit or Examples
Reference Resources		
Laser Commissioning Flowchart Laser Pointer ANSI Standard Outline Bibliography		
Program Administration		
Preamble BNL Gen Laser Preamble Use Permit	Laser Registration Form 2 and 3A User Permit	
Standard Operating Procedures (LCA-SOP)		
Introduction Commentary Annotated SOP	SOP Template	ATF SOP CAD SOP DUV-FEL SOP Biology SOP (Lab System) Mie Scattering Lidar SOP (Field System)
Engineered and Administrative Controls		
Administrative Controls Matrix		LEAF Administrative Controls Chemistry Department Inspection Checklist
Alignment		
Alignment Guidelines		Biology Example CAD/RHIC Example
Interlocks		
Guidance for Interlocks		Instrumentation Test Procedure Useful Component Specifications
Training and User Qualification		
Eyewear Guidance	Laser Eye Examination Form Training Checklist Template Training Log Form	SDL Laser Eyewear Requirements
Working Procedures		
		ATF YAG Laser Turn On Instrumentation Ti:Sapp Instrumetation Dye Laser

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser System - Specific Training Checklist

Effective Date:**Jan 23, 2015**

The Laser System-Specific Training Checklist is provided as a Word file.

LASER SYSTEM-SPECIFIC TRAINING CHECKLIST

Laser User:	
Laser Owner:	
Laser System:	

Topic	User Signature / Date	Owner Signature / Date
General Laser Safety • Laser classifications • Laser hazards • Maximum permissible exposure • Good practice in the lab		
LCA Interlock Instruction • Configuration • Operation		
Description of Laser Output Characteristics • Wavelength • Pulse energy • Average power		
Associated electrical hazards • Power supply • PMT detectors		
Normal Operation • Power on/off • Shutter operation • Normal experimental configuration • Nominal hazard zone		
Non-Normal Operation* • Gross alignment • Troubleshooting		

** Only those users who have completed the Non-Normal Operation portion of the laser-specific training may perform gross alignment procedures as defined in the Standard Operating Procedure.*

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser User Medical History and Examination Form with Instructions

Effective Date:**Jan 23, 2015**

The Laser User Medical History and Examination Form with Instructions is provided as a Word file.

BROOKHAVEN NATIONAL LABORATORY (BNL)
OCCUPATIONAL MEDICINE CLINIC (BNL-OMC)

LASER USER MEDICAL HISTORY AND EXAMINATION FORM WITH INSTRUCTIONS

Purpose of the attached Form

The purpose of the attached two-part form is to provide BNL-OMC with information necessary to determine that an individual to be cleared as a laser user at BNL has met the medical requirements of ANSI Standard Z136.1-2000 (Appendix E) governing the safe use of lasers.

This standard requires each Class 3B and 4 laser user to have a preassignment eye examination by an ophthalmologist, which is recorded on Part B of the attached form. Based upon medical history and type of laser, a preassignment skin examination performed by a BNL-OMC physician may also be required.

Instructions to BNL Host/Supervisor

Please give this form to the prospective laser user, as soon as possible. It may be necessary to forward this file since the SBMS links are generally not accessible offsite.

Instructions to Laser User

As soon as possible:

1. Contact one of the contracted local ophthalmologists from the list on the next page and request an appointment for a "laser eye exam for Brookhaven Lab." (Note: You may also obtain this exam from a Board Certified ophthalmologist other than those listed, but BNL cannot guarantee payment—consult with your BNL supervisor or host to discuss payment issues. Note also that no matter which ophthalmologist performs the exam, it must be recorded on Part B of the attached form—see step #4 below.)
2. Complete Part A of the form. This provides BNL-OMC with needed contact and medical information.
3. Give the completed form to your ophthalmologist, including this instruction page, the completed Part A, and the blank Part B.
4. Your ophthalmologist should record his/her examination on Part B of the form and forward the form to BNL-OMC as instructed below.
5. After receipt of the form, BNL-OMC will contact you if additional information or a skin examination is required.

Instructions to Laser User who wishes to submit a recent laser eye exam in lieu of having a new eye exam

A laser user who has already had a laser eye exam can submit this exam to BNL-OMC in lieu of a new laser eye exam. BNL-OMC will then consider whether the submitted exam is acceptable, or whether a new exam will still be required. Generally, to be acceptable, the submitted exam must

- be performed by a Board Certified ophthalmologist;
- provide substantially the same information that is requested in Part B of the attached form;
- have been performed within the last 3 years, with no laser eye accidents or changes in vision subsequent to the exam.

BROOKHAVEN NATIONAL LABORATORY (BNL)
OCCUPATIONAL MEDICINE CLINIC (BNL-OMC)

Instructions

The laser user who wishes to submit a recent laser eye exam for consideration by BNL-OMC must do the following

1. Fill in Part A of the form.
2. Fax Part A of the form to BNL-OMC at **631-344-7366**, along with the written record of the laser eye exam. (If unable to fax, mail as soon as possible to BNL-OMC at the address below.)
3. BNL-OMC will contact you if additional information or examinations are required.

Instructions to ophthalmologist

1. Please record your laser user eye examination on Part B of the attached form.
2. As soon as possible, please fax completed Parts A and B to BNL-OMC at **631-344-7366**. This is a secure, clinic fax that can receive confidential medical information. BNL-OMC's voice number for problems or questions is 631-344-3670.
3. If you cannot fax the completed form, please mail it to

Occupational Medicine Clinic
Brookhaven National Laboratory
Bldg. 490
Upton, NY 11973-5000

Thank you.

Contracted Local Ophthalmologists

Dr. Charles Rothberg
331 East Main
Patchogue, NY 11772
631-758-5300

East End Eye Associates
Dr. Lewis Roberts
669 Whiskey Road
Ridge, NY 11961
631-744-8020

BROOKHAVEN NATIONAL LABORATORY (BNL)
OCCUPATIONAL MEDICINE CLINIC (BNL-OMC)

Part A: Laser user contact information and brief medical history—to be completed by laser user

Name _____Life/Guest# _____ Date _____

Usual/permanent address_____

Usual/permanent phone # _____ e-mail _____

BNL address_____ BNL extension _____

Name of BNL supervisor, sponsor, or host_____ BNL extension _____

If at BNL on a temporary basis Expected arrival date_____ Expected departure date_____

What types of lasers will you be working with or near? ____UV ____Visible _____IR ____Other (Specify)_____

Brief medical history

Please list current medications: _____

_____

Do you have either of the following conditions?

_____ Aphakia (absence of a lens in one or both eyes)

_____ Photosensitivity - unusual sensitivity of the skin or eyes to sunlight or other light.

Please describe if you checked either of the above:

Laser user signature: _____

Instructions to laser user: After completing Part A, give the entire form, including instructions, Part A and Part B, to the examining ophthalmologist. Exception: If you are submitting a prior laser eye exam to BNL-OMC in lieu of having a new exam, submit this page (Part A) along with the record of that exam (see the instruction page for details).

BROOKHAVEN NATIONAL LABORATORY (BNL)
OCCUPATIONAL MEDICINE CLINIC (BNL-OMC)

Part B: To be completed by ophthalmologist

Examinee name _____ Date of exam_____

Current complaints: _____

Ocular history: _____

Pertinent family history: _____

Ocular Examination

Visual acuity

Far Point

	Uncorrected	Corrected
OD		
OS		

Near Point

	Uncorrected	Corrected
OD		
OS		

Refraction: _____

_____

Macular function (by Amsler grid or other pattern): _____

Visual fields: _____

Color vision: _____

Intraocular pressure (if over age 40 or otherwise indicated): OS _____ OD _____

Pupils and motility: _____

Anterior segment: _____

Fundus: _____

Impression: _____

_____

Examiner Information

Ophthalmologist name and title (printed): _____

Signature_____

Medical License # and state_____ Phone #_____

Office address_____

- Ophthalmologist: Forward completed Parts A and B to BNL-OMC, Bldg 490, Upton, NY 11973-5000.
- If any questions or problems, call 631-344-3670.

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Laser User Qualification Form

Effective Date:**Jan 23, 2015**

The Laser User Qualification Form is provided as a Word file.

LASER USER QUALIFICATION FORM

Personnel qualified to work with this laser system are listed below. These Qualified Laser Operators must understand the information and conform to the requirements contained in this document. For training and medical surveillance, enter the date of completion. Laser-Electron Accelerator Facility (LEAF) specific laser training and the types of work users are qualified for is documented using the separate training certification form below.

Qualified Laser Operators (see individual training certificates for level of qualification):

Basic Laser Training*	Medical Surveillance	Printed Name	Life Number	Signature	Owner/ Operator Initial/date

* Re-qualification every two years, dates are available in the training database

Training certification for laser users in Building 555, Rooms 23 and 25 (LEAF)

Training for Laser User:	
On laser system:	All lasers at LEAF

Topic	Signature of user/date (Initial of laser owner)
Instruction in interlock configuration for laser access restricted area (room or enclosure)	
Description of laser output characteristics (wavelength, pulse energy, length of pulse and/or average power)	
Checklist of major hazards (including laser light, compressed gases, cryogens, electrical): • Wear eye protection for invisible beams at all times when laser emission is possible. This includes both the laser room and the vault. • Never intentionally direct a beam towards your face, or put your face in line with any laser beam: **do not depend on eyewear to protect you**. • Be aware of what your co-workers are doing, and alert them to any potentially hazardous conditions or actions. • Use minimum laser power possible during alignment. • Use plain or fluorescent sensor cards or IR viewers when possible to aid in locating laser beams. • Locate all surface reflections and terminate with appropriate beam dumps. • Use *COMMON SENSE* and *CARE* in performing all alignments. Think about the consequences of your actions, as it pertains to the safety of yourself, others and equipment. • If unsure about what you are doing, STOP! Ask a knowledgeable person what to do before proceeding. • Don't grossly align lasers at high power. • Don't place optical elements into the laser beam without first blocking the beam with an appropriate dump. • Don't wear any reflective materials (such as rings, watches, BNL badge) on your hands or arms, or around your neck during the arraignment. • No *unauthorized* personnel are allowed in the laboratory during laser operation. • When adjusting the amplifier pump energies, take care not to put objects and/or fingers in the pump beam.	
Operation: Power on/off, shutter operation, normal experimental configuration, nominal hazard zone where class IV intra-beam beam protection is required, adjustment of bema energies via waveplate/polarizers.	
Normal maintenance: Changing laser lamps, filters, minor experimental alignment.	
Non-normal operation: Cases where additional advice/training is required. Examples: replacing damaged components, gross configuration/alignment changes.	
For students/postdocs: one-on-one training with PI: Trainer:	

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

Semiannual Laser Safety Inspection and Action Item Checklist

Effective Date:**Jan 23, 2015**

The Semiannual Laser Safety Inspection and Action Item Checklist is provided as a Word file.

Elements to include in the Laser Tier I inspections

Administrative Controls

1. Are the SOP authorizations current, all required signatures in place?
2. Are warning signs for the lab/area in place?

Laser Inventory

1. Does the SOP reflect the current inventory of lasers in the lab/room?
2. Are any other lasers expected to arrive?

Personnel Authorizations

1. Is the Laser Safety Awareness training (TQ-LASER) up-to-date (within past 2 years)?
2. Is the laser specific training documented, and up-to-date for all listed users?
3. Is the authorized users list current?
4. Are any other laser users expected to arrive?

Door Interlock System

1. Are all active lasers interlocked as required (class 4 mandatory)?
2. Is there a test procedure?
3. Have the interlocks been tested within the last six months?

Engineering Controls (other than interlocks)

1. Are enclosures and barriers present to reduce risk of exposure?
2. Are beams properly terminated where appropriate?
3. Does the diagram/schematic reflect the current configuration/geometry?

Personnel Protective Equipment

1. Is the eyewear adequate (as specified in the SOP), accessible, clean and stored appropriately?
2. Available for new lasers?

Semiannual Laser Safety Inspection and Action Item Checklist

Room No.:		**SOP Control No.:**		
Owner/Operator:	*Print Name*	*Signature*	**Date:**	
Inspector:	*Print Name*	*Signature*	**Date:**	
Laser Safety Officer:	*Print Name*	*Signature*	**Date:**	

A	***P***	***Item***	***Required corrective or other action(s)***
Administrative Controls			
		SOP authorizations current	
		Correct door signage in place	
Laser Inventory			
		SOP consistent with active inventory	
		New laser arrived or expected	
Personnel Authorizations			
		Web laser training current for all	
		Laser specific training current for all	
		SOP personnel list current	
		Medical surveillance for all	
		New users arrived or expected	
Door Interlock System			
		All active lasers interlocked	
		Logbook current	
Engineering Controls			
		Enclosures & barriers adequate	
		All beams properly terminated	
		Recent changes in NHZ / beam path	
		Recent changes in experimental geometry	
Personal Protection Equipment			
		Eyewear adequate and accessible	
		PPE for New lasers available	
Other			
		Power supply cabinets closed	
		Excimer laser ventilation	

A *= Action required,* ***P*** *= Passed (No action required); If corrective or other action is required, owner/operator shall confirm that specified action is completed, sign and date below, and return this form within two weeks to the Department Laser Safety Coordinator or ES&H Coordinator.*

This space reserved for additional comments from the inspector and/or feedback from the owner/operator

I certify that the above specified actions have been completed.

Print Name	*Signature*	Date

Management System: ***Worker Safety and Health***

Subject Area: ***Laser Safety***

System Training Log

Effective Date:**Jan 23, 2015**

The System Training Log is provided as a Word file.

System Training Log

System Description:
Location:
System Owner/Operator:

This sheet provides a local record of training for working within a specified Laser Controlled Area (LCA). It should provide information regarding users, required training, date of completed training, and verification by the installation owner/operator that the training has been completed and understood at a satisfactory level by the user. As the system expert, the owner/operator should 'self-train' and log the training on the first line of the form. When new or revised training requirements arise, they can be handwritten into a blank column. The date and initials of both the user and owner signify completed training. This record should be updated to reflect current training requirements during the annual review of the LCA-Standard Operating Procedure (LCA-SOP).

Name/Life No.	Eye Exam	Laser Safety Awareness Training	SOP (#) Rev n	Job Specific Training Rev x			
Owner/Operator (Self Training)							
User							
Owner							
User							
Owner							
User							
Owner							
User							
Owner							
User							
Owner							