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: MOS laser curvature measurement system - Thin Film Deposition Lab
Location: 703, E2/E4

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: Ray Conley	*Signature: on file*	*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) *C. Weilandics*	*Signature* *On file*	*Date*
Department ES&H Coordinator (printed name) *L. Stiegler*	*Signature* *On file*	*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.

The most pertinent document to review is the work planning document for the deposition laboratory Photon Sciences Review Form, PS-PSRF-Thin-Film

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)
Diode	630nm	3B	35mW	CW	CW	1-2mm

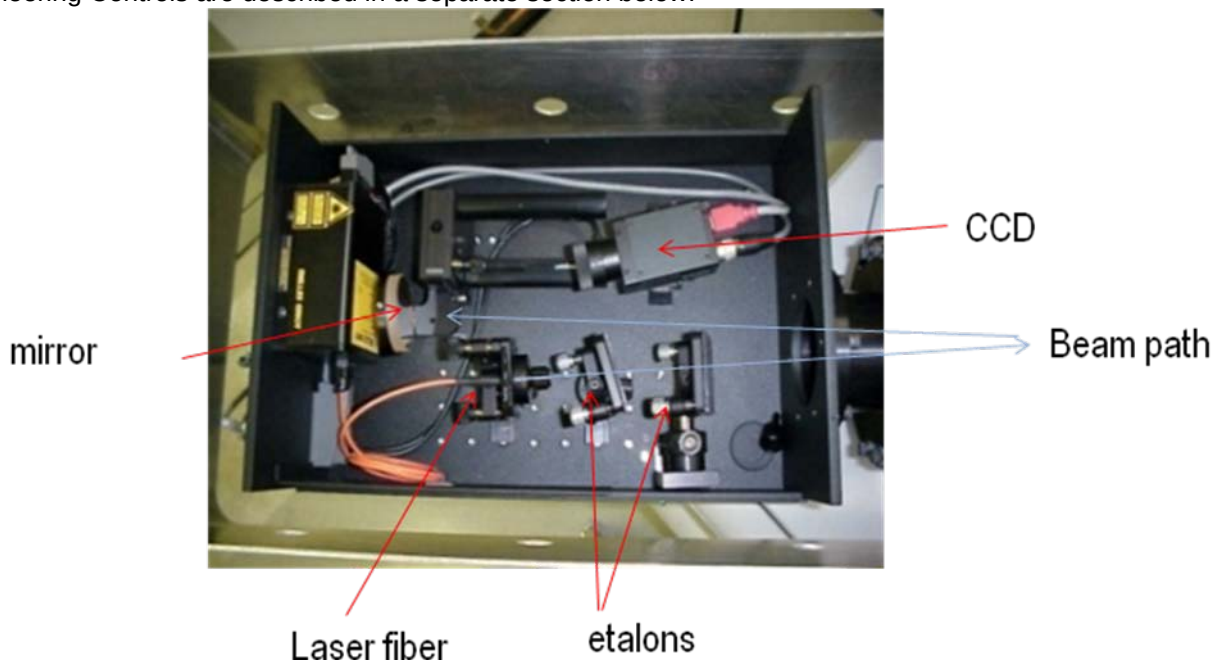
Applicable Laser Operations:

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).

The laser system consists of a small, enclosed box which houses the laser and accompanying optics. The laser system consists of the laser emitter, two etalons, a pass-through into the deposition chamber, to a servo system for beam-steering, then on to detection with a CCD camera. The single beam is split into a grid by the etalons with a defined spacing. As a wafer is bent due to film growth, this curvature results in a change in grid spacing for the laser grid. Observing the grid spacing change allows us to determine film stress in-situ. When the machine is aligned properly, the box is entirely enclosed and is mated with the deposition system chamber.

The laser system is a class 1 when under this mode of normal operation. The hazard ONLY exists when the box is opened for optics alignment. In fact, the beam that exits the box into the vacuum chamber is always a class 1 beam, since it is passing through the double etalons.

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).

The entire system is housed in a black, screwed on cover when under normal operation.

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
Interlock Safety Subject Area

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:

A series of allen-head cap screws require removal before the box enclosure can be opened for access to the class 3B laser.

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. The laser is to be operated at the lowest possible power for adequate alignment (e.g. 8-10 mW).

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).

Laser safety goggles with an OD specified in the EYEWEAR REQUIREMENTS table are required to be used with this laser system.

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.

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.

3. Consider the use of low power class 1-3A/3R 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. Pre-position optical components during gross alignment as best as possible and bolt them down before allowing beams to propagate.

9. 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.

10. 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 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 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.

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.

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)
Diode	630	3B	35mW	Cont.	NA	1-2 mm

EYEWEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
Diode	630	1.5	NA	NA	NoIR LaserShield - DIA

EYEWEAR SPECIFICATIONS		
Laser System Eyewear Identification***	Wavelengths	Optical Density
NoIR LaserShield - DIA	630-700 nm	1.5+

*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. **The system-specific training checklist is in Attachment 1.**

All Laser Training shall be documented on the On-The-Job Training form found here:
http://www.nsls.bnl.gov/training/Courses/Lasers/

All laser safety training must be repeated every two years.

Attachment 1

Laser System Specific Training Topics:

1. General Laser Safety
    a. Laser classifications
    b. Laser hazards
    c. Maximum permissible exposure
    d. Good practice in the lab

2. LCA Interlock Instruction
    a. Configuration
    b. Operation

3. Description of Laser Output Characteristics
    a. Wavelength
    b. Pulse energy
    c. Average power

4. Associated electrical hazards
    a. Power supply
    b. PMT detectors

5. Normal Operation
    a. Power on/off
    b. Shutter operation
    c. Normal experimental configuration
    d. Nominal hazard zone

6. Non-Normal Operation*
    a. Gross alignment
    b. Troubleshooting