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: Pulsed laser deposition system for thin films growth.
Location: NSLS-X21

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: Randy Headrick	*Signature:* *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.

BNL LSO printed name	*Signature*	*Date*
Chris Weilandics	Signature on file	
Department ES&H Approval printed name	*Signature*	*Date*
Lori Stiegler	Signature on file	

APPLICABLE LASER OPERATIONS
☒ Operation ☐ Maintenance ☐Service ☐Specific Operation ☐Fiber Optics
ONLY GENERAL OPERATION. LASER ALIGNMENT, SERVICE/REPAIR WILL BE PERFORMED BY TUILASER AG. SLIGHT ADJUSTMENT OF THE FIVE MIRRORS OUTSIDE THE LASER MAY BE NECESSARY.

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
KrF Excimer laser	248nm	4	250mJ	20ns	100Hz

☐ **Cryogen Use**

Describe type, quantity, and use.

None

☒ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

Compressed laser gas premix (F_2 0.1%, Kr 3.93%, He 1.71%, Ne balance) is used. The laser typically will be refilled once or twice a month depending on how often the laser is used. The refilling process is automatically controlled by the laser itself. Stainless tubes are used to connect the compressed gas tank to the laser. The gas premix cylinder is enclosed in a vented cabinet and the gas exhaust of the excimer laser is also vented through a hood to the ventilation system of the building. The annual expected usage is 3 cylinders (3L, 15Mpa).

☒ **Electrical Hazards**

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

Normal power supply of 200V-240V, 50-60 Hz, 1 phase, 16A max, 3kW. Power supply is fully contained inside the laser.

There are capacitors inside the cabinet. Use caution if the cover needs to be open for the halogen filter changing, keep away from capacitor bank..

☒ **Other Special Equipment**

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

An External cooling system may be used to cool the excimer laser at rep rates greater than 10 Hz.
Model: KüHLMOBIL, type KM 12. Cooling agent: water. 110V, 1.7A, 170W.

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)*.

The laser has one switch, and one control keypad with one switch key. For the beam path and optics, please see the attached X21 picture for detail.

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)

Brookhaven National Laboratory Standards Based Management System (SBMS) Subject Area Laser Safety

Brookhaven National Laboratory Standards Based Management System (SBMS) Subject Area Electrical Safety, Section 6, 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 Enclosures: Laser beam is all enclosed in an exclusion zone between the laser and the vacuum chamber. The exclusion zone will only be open during the optics alignment, which is normally not needed.

Beam Stop or Attenuator: The laser is supplied with an external manually controlled shutter.

Activation Warning System: The startup process for the laser incorporates a variety of steps to serve as an indicator that the laser is powered and capable of emission.
Ventilation: All gases used in the laser system are vented through a ventilation system to the outside of the building.
Other (laser controlled area) interlocks: Interlock switches on the doors provide an interlocked controlled area. An indicator light outside is active when the laser is powered and capable of emission.
Other: An external cooling system may be used, which is for cooling the excimer laser.

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: A laser controlled area is established via interlocked access (see engineering controls). The X21 hutch is the laser controlled area.

Laser signs are present on the door and labels are in place on the laser. The lab is a laser controlled area. Only qualified personnel are allowed to enter the lab during its operation.

The X21 Gas Checklist is performed prior to operation (Attachment 2)

The X21 Pre-operational Safety Checklist is completed prior to operation (Attachment 3)

The laser in X21 is intended to be used to hit a solid target to evaporate materials off from the target within a chamber and deposit them into a substrate to form a thin film of the material which has the same composition of the target material. The laser is only used during this deposition period, which is dependent on the desired film thickness. The beam is focused to have much higher energy density before it hits on the target surface. Lens is put on just before the beam gets into the vacuum chamber. Below are the **Standard Operating Procedures (SOPs)** associated with the Excimer laser in X21.

General Operation

1) Whenever the interlock is enabled, user has to put his/her goggle on.
2) Any intended user has to be trained by the authorized trainers listed in the laser documentation binder to do the PLD experiment in addition to the other regular laser safety training before he/she can do any experiment in X21.
3) Before starting your experiment, check the interlock test to see whether it is in working status.
4) If needed, be sure to turn on the water-cooling system before you start the excimer laser.
5) Be sure that laser beam exclusion zone is fully enclosed before you start the laser.
6) General operation only involves starting the laser, choosing laser firing energy and rep-rate, slight

optics adjustment, and stopping the laser from the laser control pad. No other operation of laser is allowed.

7) If a slight adjustment of the beam is necessary, stop the laser, open one door of the exclusion zone, adjust the two screws of the mirror as intended, close the door, start the laser. If more adjustment is needed, repeat this procedure. Adjustment must not be done when the laser is firing.

Maintenance

1) Laser maintenance only involves gas refilling for the laser, which is typically once or twice a month. It's a standard procedure documented in the user manual of the laser and is automatically controlled by laser itself. This work is currently done by laser owner only. No one else is authorized to do so.
2) The Halogen filter should be exchanged every time the Pre-Mix gas bottle is replaced. This work is currently done by laser owner only. No one else is authorized to do so.
3) Ensure that an interlock test is performed at least every six months.
4) Other laser service and repair are performed by the manufacturer as needed.

Alignment

1) Laser beam alignment inside the laser is only serviced by manufacturer when needed.
2) 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.
3) Skin protection is to be worn on the hands and arms when aligning at UV wavelengths.
4) Slight optical path alignment for general operation is documented in General Operation procedure 7).
5) For adjustment of the mirrors in the optical path, which is not needed very often after it is done at beginning, use the laser in its minimum power and repetition rate (20KV at 1Hz) and separate the adjustment and test procedure. This means, when in adjustment, turn off the laser, when in test for alignment (laser has to be turned on), close the exclusion zone, put on the goggles, make sure that the beam path is all enclosed. Currently, this alignment is only done by authorized trainers.

Service/Repair

Laser service and repair are only done by manufacturer as needed.

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. See also the Pre-operational Safety Checklist, Attachment 3

1) Exclusion Zone for laser beam path has to be fully closed.
2) Interlock system with the door of the lab has to be enabled.
3) Pay attention to the five mirrors inside the exclusion zone for redirecting laser beam.
4) Emergency Stop button for laser.

5) Laser on sign outside the lab on the door.
6) Interlock system test logbook.
7) Laser specification label on laser.
8) Laser Controlled Area Checklist, Attachment 1.

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.

N/A

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***
KrF Excimer laser	248nm	7(10s)	3.6(600s)	12.6 meters	GPT Glendale D10600L2 GPT glass eyewear

* 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
GPT Glendale D10600L2 GPT glass eyewear	248nm	190-360nm, OD>9 5000-11000nm, OD>7

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 topics are documented in Attachment 4.** Laser training is documented on the NSLS OJT Laser Training form.

All laser safety training must be repeated every two years.

Attachment 1: Laser Controlled Area Checklist

The laser in X21 is used to evaporate materials from a solid target and deposit them onto a substrate to form a thin film of material having the same composition as the target material. The laser is only used during this deposition period. The operating time depends on the desired film thickness. The laser beam is focused to provide a higher energy density on the target surface. Lenses are placed just before the beam enters the vacuum chamber.

General Operation

1) Whenever the interlock is enabled, users must wear goggles.
2) Any intended user has to be trained by the authorized trainers in addition to the other regular laser safety training before he/she can do any experiment in the PLD lab (X21).
3) Before starting the experiment, check the interlock test to make sure it is in working status.
4) If needed, be sure to turn on the water-cooling system before starting the laser.
5) Be sure that the laser beam exclusion zone is fully enclosed before starting the laser.
6) General operation involves starting the laser, choosing the laser firing energy and rep-rate, a slight optics adjustment, and stopping the laser from the laser control pad. No other operation of the laser is allowed.
7) If a slight adjustment of the beam is necessary, stop the laser, open one door of the exclusion zone, adjust the two screws of the mirror as intended, close the door, and restart the laser. If more adjustment is needed, repeat this procedure.
8) Note, only the above alignment is allowed by authorized user. Any major alignment of the optics path must be performed by the laser owner.

Maintenance

1) Laser maintenance involves refilling the gas supply to the laser, typically once or twice a month. It is a standard procedure documented in the laser user manual. This work is currently done only by the laser owner. No one else is allowed.
2) The Halogen filter should be exchange every time the Pre-Mix gas bottle is replaced. This work is currently done by laser owner only. No one else is authorized to do so.
3) Ensure that an interlock test is performed at least every six months.
4) The main maintenance and repair are performed by the manufacturer as needed.

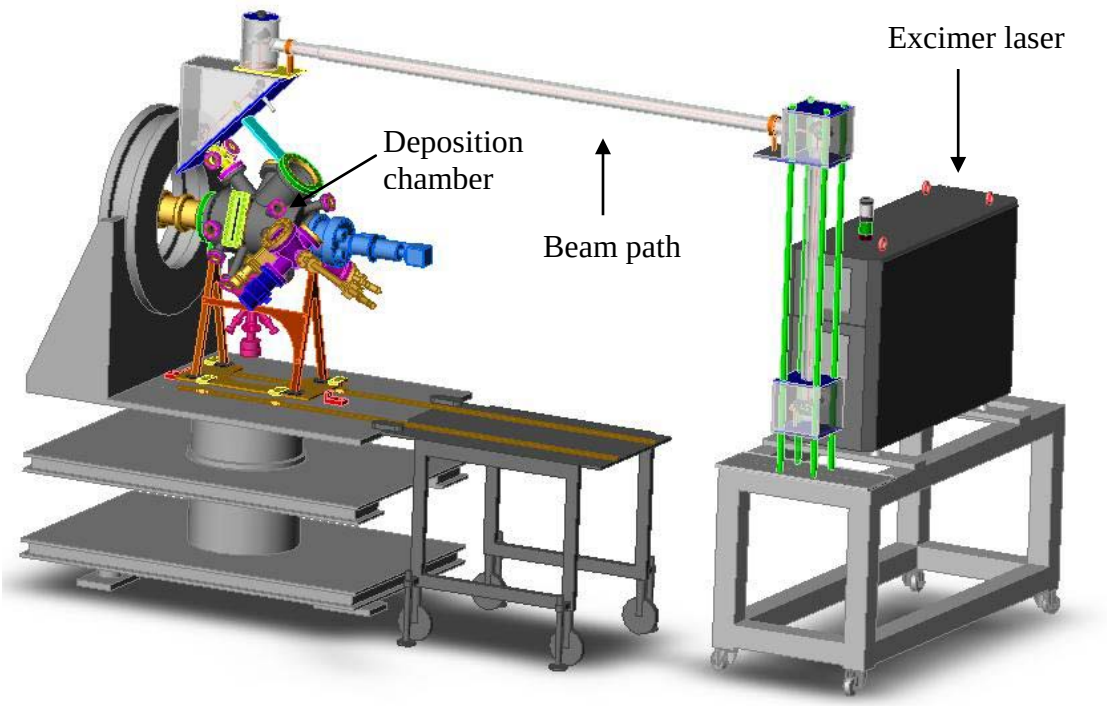
Alignment

Laser beam alignment inside the laser is performed by the manufacturer as needed. External optics path alignment is documented in the General Operation procedure 6) and 7).

Service/Repair

Laser service and repair are performed by the manufacturer as needed.

X21 setting



1) The laser beam is enclosed in the exclusion tube before it reaches the target in the deposition chamber.

2) The laser beam is guided by five adjustable mirrors and one focus lens to reach the target.