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:
A laser heating system for diamond anvil cell experiments has been installed at X17B3. A class 4 ytterbium fiber laser (IPG model YLR-100-SM-CS) is used to perform high-pressure laser heating of samples contained in diamond anvil cells. Included within this laser is a guide laser which operates at 670 nm with an output power of < 1 mW and a class 3B DPSS alignment laser (Laser mate GMR-532-30FBC1) with a maximum output power of 30 mW.
The 30mW DPSS laser is used as guide laser to align/check the heating system optics. The use of the fiber laser will be addressed in heating operations.

Location:
The lasers are located in the X17B3 hutch of Building 725.

LINE MANAGEMENT RESPONSIBILITIES

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

Owner/Operators:

Name:	*Signature:*	*Date:*
Xinguo Hong Zhiqiang Chen Amartya Sengupta	On file	

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*

Department ES&H Approval 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 SYSTEM CHARACTERISTICS					
Laser Type *(Argon, CO_2, etc.)*	Wavelengths	ANSI Class	Maximum Power or Energy/Pulse	Pulse Length	Repetition Rate
Ytterbium Fiber Laser	1060-1080 nm	4	100 W	CW	N/A
Diode guide laser	670	2	<0.001 W	CW	N/A
DPSS Alignment laser	532	3B	30 mW	CW	N/A

☐ **Cryogen Use**

No cryogens are used as part of the laser heating system.

☐ **Chemicals & Compressed Gasses**

No chemicals or compressed gases are used as part of the laser heating system

☑ **Electrical Hazards**

The Yb fiber laser and the DPSS laser operate at single-phase 110-220 VAC, 50/60 Hz and is grounded at the line power connection.

Alignment and operation of these laser systems requires no work on the power supplies. No users are authorized to work on the laser power system. Any maintenance or troubleshooting of the power system for these lasers will be done by a qualified technician employed with the

system manufacturer. Should that service be needed, formal work planning is required and must be coordinated with the NSLS Work Control Manager.

☑ **Other Special Equipment**

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

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)*.

A schematic of the optical system is included below as appendix #1.

Diode laser: The <1 mW, ANSI Hazard Class 2, laser is used to align the beam path of the Ytterbium fiber laser. It is not interlocked for personnel protection. The measured power along the open beam path is <1 mW.

Yb:fiber laser: The 100 W, ANSI Hazard Class 4, system is used to heat samples within diamond anvil cells while x-ray diffraction experiments are conducted with the synchrotron beam. Although capable of 100 W of output power, the system is typically operated at 0-30 W during routine operation. The laser heating experiments can have durations up to ~2 hours of continuous laser use.

DPSS Solid State Laser: This 30 mW ANSI Hazard Class 3B laser is used for alignment of the laser heating system. Eyewear for the DPSS system (see Eyewear Requirements Table) will be worn during alignment and checking of this system.

Beam combiner: The combiner is the High-energy Nd:YAG laser mirror (Newport 10Q20HE.1) which is manufactured using high purity fused silica substrates and ultrahard dielectric coatings. This reflectivity of this mirror is more than 99% @ 1064 nm and transparent for green and red guide laser. No mechanical movement is needed while switching guide and heating lasers.

Heating system setting up: All guide and heating lasers are set to pass through a line formed by two pinholes. Additional two pinholes are used to constrain upstream and downstream laser paths, respectively. The heating experiment can be simulated and viewed on monitor using DPSS green guide laser.

Computer control: The system is well motorized and easy to use for precisely and remotely controlling the guide and heating laser. Two prosilica cameras (Prosilica GC1380H) are used to view the sample and laser beam via Mark River's area detector software.

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

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:

Beam enclosure is made by 2mm thick anodized aluminum sheet. At the diamond anvil cell side, there is a anodized aluminum curtain to provide protection for scattered laser beam. Only the Owner/Operator can open the enclosure for alignment/checking.

Beam Stop or Attenuator:

Water cooling beam dumper is needed for high power laser. It contains an inner water cooling cooper plate with Tungsten in center to dump direct laser beam and anodized aluminum cubic to absorb the scattering laser beam.

Key Controls

The laser has a key control on the power supply. The keys are kept under the control of the laser owner/operators.

The personnel protection interlock has a lock-out key. That key and a spare are kept in the NSLS control room. The system is not normally locked out with this key.

Emission Delay

When the laser is switched on, emission commences only after an emission delay set by the manufacturer.

Activation Warning System

The laser has an activation indicator that lights up when the laser is energized.

Personnel Protection Interlocks (Other Interlocks)

The personnel protection interlocks in service at X17B3 were designed, installed, and are maintained and tested by the NSLS Interlock Working Group. The system is configured to control the position of the Yb:fiber Emission Enable Input to assure that the laser controlled area is secured before allowing laser emission.

The guide laser or DPSS outputs are not included in the personal protection interlock hardware or logic.

A detailed description of the personnel protection interlock is included here as Appendix #2.

The personnel protection interlock must be tested and shown to operate as expected every 6 months. This schedule is tracked by the NSLS Interlock QA Manager.

ADMINISTRATIVE CONTROLS

☑ Laser Controlled Area ☑Signs ☑Labels ☑Operating Limits

Administrative Controls Description:

Laser Controlled Area

The X17B3 hutch acts as the Laser Controlled Area for both laser systems. The hutch windows are covered by anodized aluminium sheets, i.e. “light tight.” For control against unauthorized access, the entrance door switch is part of the laser interlock. In the event of an unauthorized entry, the interlock to the laser will open and the laser emission stops.

Signs and Labels

A warning sign provided by the BNL LSO is posted at the entrance to the Laser Controlled Area. For the purpose of alignment using the 30 mW DPSS, a laser warning sign will be provided for the DPSS laser as well as a “NOTICE” sign, denoting that alignment is taking place
The manufacturer of each laser has affixed warning labels to each device that indicate the ANSI hazard class of each laser.

Operating Limits

See Appendix #3 for the SOP for the X17B3 laser heating system.

PERSONAL PROTECTIVE EQUIPMENT

☐ Skin Protection ☑ Eye Wear

Eye Wear:
There are 4 pairs of eyewear available for use at X17B for protection from the Yb:fiber system. These eye glasses are stored in their manufacturer supplied cases and kept in the cabinet in the X17B3 beam line hutch. Each pair of eyewear is labeled with the optical density and wavelength for which protection is afforded. Eyewear is to 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.

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***
Yb:fiber	1060-1100	4.7 (100W)(10sec) 4.4 (50W)(10 sec) 4.2 (30W)(10 sec)	1.2OD 0.9OD 0.7OD	0.8m 0.56m 0.44m	Yb Fiber laser protective eyewear Model 3982 or 3987
DPSS Alignment laser	532	3.5 (0.25sec)	NA	0.03	GPT Eyeware (LASER-GARD ARGON)
Diode guide laser	670				No Need

* 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
Glendale Laser Eyeware Model 31-3982 (2 pair available)	810-1100 nm	>7
Glendale Laser Eyeware Model 31-3987 (2 pair available)	190-380nm 780-850 nm 850-1070 nm 5000-11,000nm	>7 3 >4.5 >7
GPT Eyeware (LASER-GARD ARGON)(1 pair)	190-520nm 532nm 5000-11000nm	>9 >4.5 >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 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.

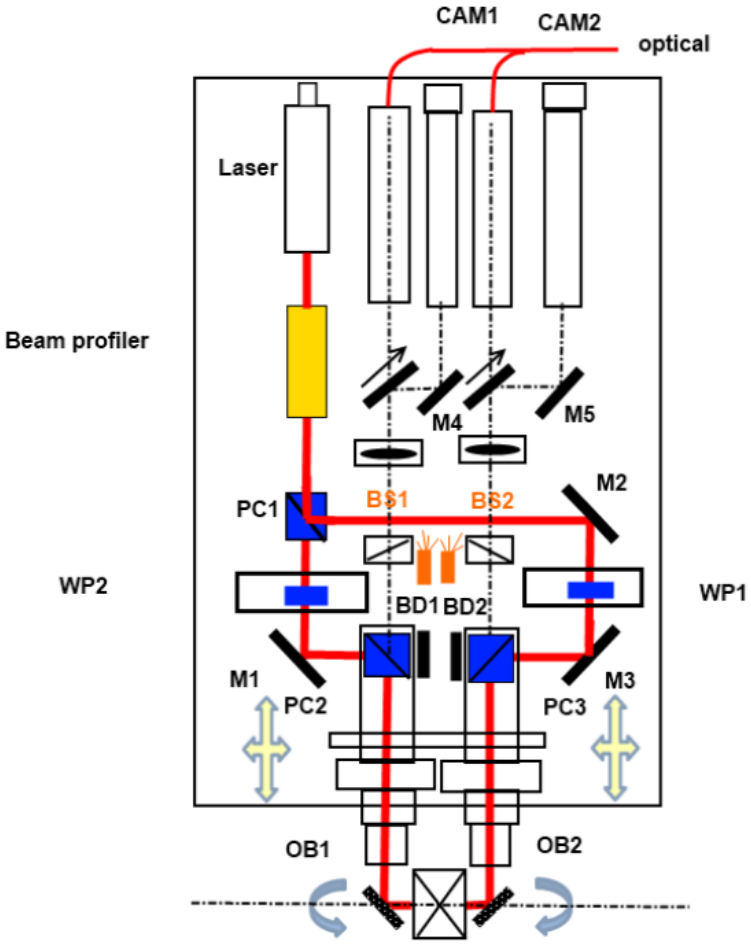
All laser safety training must be repeated every two years.

A X17B3 laser heating system specific training checklist is included here as Appendix #4

-- A current, reference copy of the X17B3 Laser Safety Standard Operating Procedure
--.
--A list of qualified laser operators that includes the name of each operator, training dates, and any required medical examinations.

Training for qualified laser operators and users will be documented on LS-TRN-CRF-0018 and submitted to the Training Coordinator for entry into BTMS.

Appendix #1. Schematic diagram of laser heating system at X17B3



Appendix #2
Personnel Protection Interlock Description

Operation of the X17B3 Laser Interlock System
Prepared by Scott Buda; 11/18/2005
Modified by Ewart Orr 05/01/2010

This document describes the operation of the NSLS Standard Laser Interlock System. A typical laser interlock system consists of a controller (PLC), a laser shutter, laser power supply and laser. The laser power supply normally has provisions for interlock inputs. The NSLS Interlock Working Group (IWG) has established this configuration as its most preferable configuration. Any configuration that differs from this has to be approved by the NSLS IWG. The laser shutter can be a commercial shutter or the low powered laser shutter designed in house. Commercial shutter designs require inspection by CE to ensure compatibility with NSLS interlock system. A single door is used to access the laser area to be protected. Once secured a lighted "Laser Interlocked" sign is displayed above the door, both inside and outside the searched area.

1. Emergency Stops
   The system has emergency stops located on each control station located inside and outside the laser controlled area. Pressing the emergency stop will remove the factory interlock from the laser power supply; removing the shutter open command and dump the interlock search. This requires an authorized operator to reset the system. An emergency stop fault can be reset by twisting or pulling the button, then use the reset key to complete the process. The area will need to be searched again to activate the interlock.

2. Area Search
   In order to operate the laser, the laser controlled area must be searched for personnel; no person can be left in the area immediately after the search is performed. To reinforce the search, a sequence of buttons must be pushed in the correct order to complete the search. To begin the search enter the laser area and visually look for personnel in the area, if no one is found; press the start search button located on the inner control station, exit the laser area and close the main entrance door. Press the complete search button located on the outer control station, the warning sound will sound for 30 seconds. After the warning is completed, the area is ready for laser light.

3. Interlock Off
   If the laser interlocked area is no longer needed to be interlocked, the interlock can be turned off in an orderly manner by closing the laser shutter and then pressing the interlock off button. This will bring the interlock to the ground state. If a door is inadvertently opened while the area is interlocked, the laser control area will lose interlock, a warning will sound and the laser responsible person will have to reset the system with the reset key and research the area.

4. Shutter control
   The shutter may be opened from either the inner or outer control station. Press the open button to open the shutter or press the close button to close the shutter. After pressing the open button two short beeps will indicate that the shutter is opening.

5. Pass Through
   A person trained and authorized may enter an interlocked laser area with the proper PPE using the pass through function. After the area is searched and interlocked, to enter the laser control area press the pass through button on the outer control station, (if the laser shutter is open it will automatically close and remain closed until commanded to open). Open the main door to enter the laser area, once inside the laser area, close the main door and press the pass through button on the inner control station. This feature allows trained and authorized personnel to enter and exit the laser area, while maintaining the interlock. This is a timed function and has a 30 second time limit. If the door is open for more than 30 seconds, the pass through function will timeout and dump the interlock.
   To exit the area reverse the process completing it with pressing the outer pass through button. When the pass through function is activated, a light on the button confirms operation.

6. Interlock Signs
   Located above the main door on the inside and outside of the laser area are Laser Interlock signs. The interlock signs are illuminated when the area is interlocked for laser operation.

7. Lockout Key
   A key switch located on the outer control station provides a means of disabling the interlock system from operating. The key must be removed after locking out the system.

Updated Design

The newer version of the laser control systems have the same basic functionalities described above. The design uses a safety PLC that is capable of detecting open and short circuit in the wiring. In addition a blue re-integration LED indicates when the PLC detected a fault or when an emergency stop was pressed. If all faults are cleared, reset system and secure laser area as described above.

NB:-If blue re-integration LED is lit on initial power-up, reset system and proceed.

Appendix #3:

Standard Operating Procedure (SOP)
X17B3 Class IV Laser Heating System

1. Laser maintenance

Maintenance procedures for the Yb: fiber laser are only to be performed by the manufacturer, IPG Photonics. Maintenance procedures for the He:Ne laser are only to be performed by the manufacturer, JDS Uniphase.

2. Laser heating system alignment procedures

These alignment procedures are only to be performed by the laser owner/Operator or Level II users.

Attention: only the Owner/Operator or Level II user is authorized to do the following alignment.

Appropriate eyewear must be worn during all alignment operations to reduce output of the alignment beam to ideally < 1mW, but in all cases to < 5mW. The eyewear used will be the GPT Eyeware (LASER-GARD ARGON)(OD >4.5 @ 532nm).

The laser is enclosed with 2mm thick anodized aluminum sheet. At the diamond anvil cell side, there is a anodized aluminum curtain to provide protection for scattered laser beam. Always place the anodized aluminum while operating and aligning the laser since it is facing the hutch door. Only the Owner/Operator can open the enclosure for alignment/checking.

Procedural Considerations

1. To reduce accidental reflections; watches, rings, dangling badges, necklaces, reflective jewelry must be 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 but only if the output of the beam is less than 5 mW. If goggles need to be used, the each individual must have goggles sufficient to reduce the transmitted beam to less than 5 mW in all cases.
4. Enclosure and protection curtain should be in place.
5. Water cooling should be running while laser heating experiment
6. All equipment and materials needed are present prior to beginning the alignment.
7. All unnecessary equipments, tools, combustible materials (if fire is a possibility) have been removed to minimize the possibility of stray reflections and non-beam accidents.
8. Persons conducting the alignment have been authorized by the RI
9. A NOTICE sign is posted at entrances when temporary laser control areas are setup or unusual conditions warranting additional hazard information will be available to personnel wishing to enter the area.

Operation procedures

Attention: Only level II users are allowed to carry out the following procedures:

- Close the door to the Laser Controlled Area (X17B3 beamline hutch)
- Never leave the system unattended during operation.
- Never try to observe laser beam directly even with safety goggles.
- Don appropriate safety goggles.
- Turn Yb:fiber laser on with the external shutter off and the rough surface brick blocks right after the shutter.

4. Operation procedures for turn on the Fiber Laser

All authorized personnel (Level II) must follow the procedure as follows:

- Close the door to the Laser Controlled Area (X17B3 beamline hutch)
- Never leave the system unattended during operation.

Appendix #4:

Training Checklist for the X17B3 Class 4 Laser Operators

Completion of the items on this checklist and the signature of an authorized trainer will constitute the record of a certificate for an individual to be a qualified operator of the Laser System. There are two levels of certificates. Level I operator are authorized to run the Lasers for laser heating experiments. Level II operators are entitled to make the laser system alignments.

Level I operator

Completion of the items on this checklist and the signature of the X17B3 Laser System Owner is required for Level I operation of the Yb:fiber laser heating system at X17B3.

☐ Read and understand the X17B3 Laser Heating System Standard Operating Procedure.

☐ Demonstrate understanding of laser heating procedure. Understand how to turn the laser on and off and adjust laser power remotely using IDL/EPICs based control system while the x17B3 station door is closed.

☐ Acknowledge that laser system operators are not permitted to work on laser power systems and are not authorized to work on beam alignment.

☐ Complete laser heating run with the system owner.

Level II Operator

☐ Completion of Level 1 operator training.

☐ Complete BNL required laser safety training, including baseline eye exam.

☐ Demonstrate understanding and operation of the laser personnel protection interlock.

☐ Identify appropriate eyewear and when use is required.

☐ Be familiar with the operation procedure. Demonstrate capability of aligning or restoring the alignment of all components of the system. Be able to assist level I operators in laser operations/alignment issues.