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: ATF Nd:YAG System
Location: YAG room; transport to gun hutch, laser lab, CO2 Amp, CO2 Main, FEL rooms

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: Marcus Babzien	*Signature:*	*Date:* 9/28/10

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.

Christopher Weilandics		9/21/10
BNL LSO printed name	*Signature*	*Date*
Michael J. Zarcone		9/16/10
Department ESH Coordinator printed name	*Signature*	*Date*
	T. Mulligan	9/17/10
Department Chair/Division Head 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.

No applicable higher level documents.

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 Dia-meter (mm)
Nd:YAG	1064	4	1064 nm 1W	7 ps ML @ 81.6 MHz	CW	2
		4	1064 nm 500 mJ	14 ps	1.5-6 Hz	6
	532	4	532 nm 200 mJ	3-10 ps	1.5-6 Hz	6
	266	4	266 nm 50 mJ	8 ps	1.5-6 Hz	6
Yb:glass	1040-1060 nm	4	250 mW	100 fs ML @ 81.6 MHz	CW	2
		4	150 μJ	200 fs	1 kHz	4
Diode	976 nm	4	50W	CW	CW	6

Applicable Laser Operations:

The ATF Nd:YAG laser system serves two primary functional roles: generate photolectrons from the facility's RF photoinjector cavity, and provide optical synchronization and slicing to the facility CO2 laser system. Both of these roles require beam transport through vacuum lines several meters or tens of meters in length. Vacuum transport is through tool-removable opaque beam pipes. Where accessible, beam pipes are labeled and locked. Most sections of beam pipe are covered by radiation shielding and inaccessible.

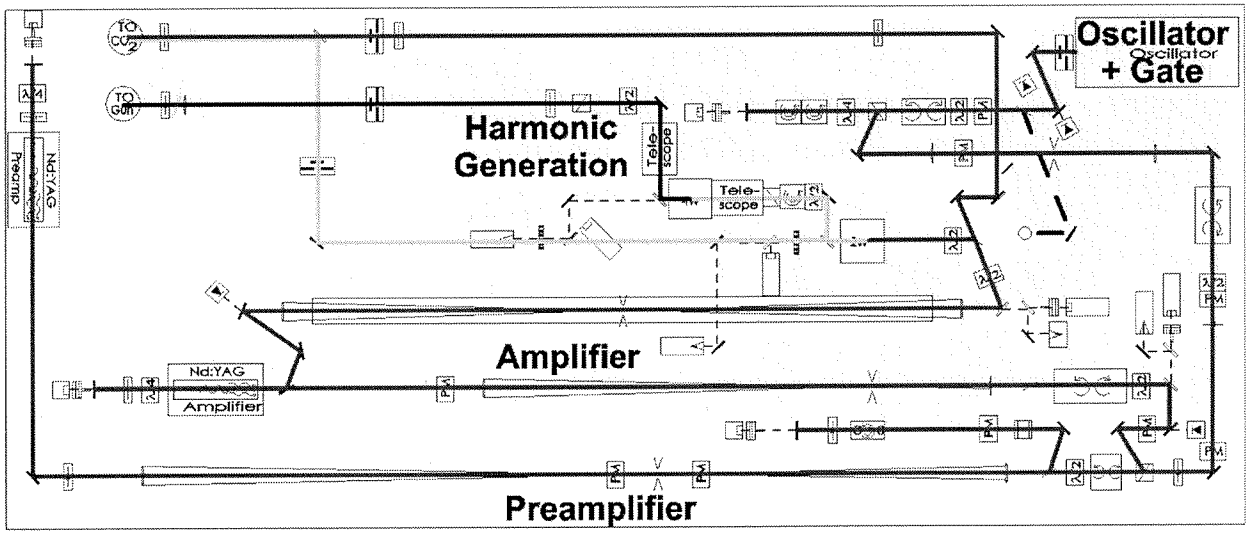
The system operates in purpose-built clean rooms dedicated to laser operations with engineering and administrative controls in place.

For details of the CO2 laser system, please refer to PO-P-ATF-0018.

Operation of the Nd:YAG laser system for both RF gun and CO2 laser operation require changing the laser state from a standby condition to a fully functional condition. This may be accomplished without entering a laser controlled area. Laser output levels and other operating parameters may be monitored remotely, and only minor access is required for trained personnel to provide full operational capabilities.

Laser System Configuration:
Refer to Drawing ATF SK-1181-5 Laser Path Layout for facility beam path details.
Refer to drawing below for YAG laser beam path:

ATF Nd:YAG Laser - functional units and beam path



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**

After certain maintenance periods, clean, high vacuum conditions must be restored in spatial filter and transport tubes in the laser system. This is partly achieved with a cryosorption pump located in the front end vestibule. The liquid nitrogen reservoir that maintains the temperature of the pump is filled by a hand carried dewar. Total volume of the reservoir is less than 3 liters when full, and requires frequent manual refill. All personnel using the cryosorption pump must complete the web-based BNL cryogenic safety awareness training course HP-OSH-025 at http://training.bnl.gov/cbt/cryogenics. Protective gloves and face shield are available at ATF for use with the liquid nitrogen.

☒ **Chemicals & Compressed Gases**

Compressed nitrogen gas is used to actuate shutters, purge optical assemblies, and periodically clean optics throughout ATF. The gas is supplied from boil-off in a portable liquid nitrogen dewar near the front end laser area in the high-bay of building 820. The gas pressure is regulated to 100 psi, and maximum flow is limited by the 0.25 inch distribution lines.

☒ **Electrical Hazards**

Several high voltage power supplies are used to provide transient pulses to Pockels Cells throughout the laser system. Maximum voltages are less than 10 kV, and currents limited to 1 mA or less DC. All power supplies and pulse generators are commercial devices and are enclosed and labeled by the manufacturers. Pockels Cell terminals are enclosed with tool-removable enclosures and labeled.

☒ **Other Special Equipment**

The diode laser operating at 976 nm is capable of producing up to 50W CW power. Because the beam size will generally be well below 5 cm, the potential exists to substantially exceed the 2 W/cm^2 threshold for igniting flammable materials. In order to minimize the potential for ignition, the beam will be terminated in a suitable beam dump whenever feasible, non-flammable enclosures shall surround the beam path to stop stray beams, and flammable materials shall be kept out of the beam enclosure.

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 Sections:

Laser Safety Subject Area
Electrical Safety Subject Area: 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:

Refer to ATF Laser Interlock System Operating Procedures PO-P-ATF-0025 for interlock description.

Refer to ATF Laser Interlock System Search Procedures PO-P-ATF-0026 for search and secure description.

Refer to ATF Laser Interlock System Test Procedures PO-P-ATF-0027 for interlock recertification process.

Class IV light from this system is only accessible in controlled areas. Rooms are secured before the light is accessible in the area (see above procedures). Transport paths from laser sources to beam blocks or between rooms are inaccessible inside light-tight enclosures that require tool-aided removal and are administratively controlled. Additional enclosures are used in controlled areas where beam placement may increase the likelihood of inadvertent exposure to authorized users, e.g. beam crosses eye-level.

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).

Refer to PO-P-ATF-0023 Nd:YAG Operating Procedures.

Maintenance/Service:

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

Refer to PO-P-ATF-0022 Nd:YAG Maintenance Procedures.

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* SBMS subject area and regulated by the *Guest and Visitors* SBMS subject area.

None required.

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.

Refer to PO-P-ATF-0024 Nd:YAG Alignment Procedures.

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).

Configuration changes occur infrequently and are detailed in system documentation used for operator training. Significant changes require formal operator retraining.

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 sun-screen creams are recommended.

None required as exposure to 266 nm is only possible at low average power.

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 (W or J)	Pulse Length (s)	Repe-tition Rate (Hz)	Beam Dia-meter (mm)
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		4	150 μJ	200 fs	1 kHz	4
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EYE WEAR REQUIREMENTS

Laser System Hazard	Wavelength (nm)	Intra-beam OD	Diffuse OD *	NHZ** (m)	Appropriate Eye Wear*** (OD)								
					Glendale (UVEX) LOTG-CO2	Glendale (UVEX) LOTG-YAG/KTP	Glendale (GPT) 31-21102	Glendale (GPT) 31-80101	Glendale (GPT) 31-80102	Glendale LSK-YAG/CO2	Glendale LSK-YAG/KTP	KG5+OG570 (spectacles w/clip-on)	KG5 (black prescription spectacles)
Nd:YAG fundamental	1064	6	3	5.8	-	7	7	7	7	7	7	6	6
Nd:YAG second harmonic	532	6	3.6	8.3	-	7	7	-	7	-	7	6	-
Nd:YAG fourth harmonic	266	5.6	2	1.7	7	7	7	9	7	9	7	5	5
Yb:glass fundamental	1050	3.7	1.2	0.8	-	5	5	5	5	5	5	6	-
Diode fundamental	976	4.5	1	0.7	-	5	5	5	5	5	5	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.

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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 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.