Subject: Laser Safety Program Documentation		
Prepared By: Brian Sheehy	**Approved By:** Xijie Wang	**Approved By:** James B. Murphy

BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
NSLS (DUV-FEL) 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: Deep Ultraviolet Free Electron Laser
Location: Source Development Laboratory, Building 729

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: Brian Sheehy	*Signature:*	*Date:*	Sep 15, 2003

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*

Andrew Ackerman		
ES&H Coordinator printed name	*Signature*	*Date*

APPLICABLE LASER OPERATIONS
x General Operation x Alignment x Service/Repair x Specific Operation □ Fiber Optics

ANALYZE THE LASER SYSTEM HAZARDS

LASER SYSTEM CHARACTERISTICS					
Laser Type *(Argon, CO2, etc)*	Wavelengths (nm)	ANSI Class	Maximum Power of Energy/Pulse	Pulse Length	Repetition Rate
1) Seed Laser	800 nm	*IIIb*	5 mJ	0.1-100 psec	10 Hz
2) FEL output (fundamental)	266 nm	*IIIb*	100 uJ	0.1-2 psec	2.5 Hz
3) FEL output (harmonics)	89 and 133 nm	*I*	1 uJ	0.1-2psec	2.5 Hz

NOTE: For all of the above systems eye protection must be worn when working with open beams

System by system breakdown:

1) Seed Laser
purpose: seed the FEL process. This can be done by overlapping the seed pulse with the electron bunch in the radiator (direct seeding) or in an undulator prior to the radiator, the modulator (in High Gain Harmonic Generation)
output: Typically 1 mJ pulses are injected into the accelerator; only a portion of this makes it through the apparatus to the FEL output window: the 2 silicon carbide mirrors constituting the periscope after the radiator each have a reflectivity of ~ 40% at the seed wavelength, and the output coupling mirror to the diagnostics is currently a dielectric mirror for 266 nm, so its reflectivity at the seed wavelength is 2 x 4% (reflections from both surfaces). The current energy is thus 2 spots of ~ 6 microjoules each. Operators should be aware however, that changes in the output optics or coupling more energy into the seed will raise that number. The current output parameters are: 1-10 psec pulses at 10 Hz, wavelength ~ 800 nm
beam paths:
   - from laser room, ~35 meters enclosed (via the RF gun hutch) to seeding table in the accelerator enclosure. From there, into the accelerator and ~ 21 meters enclosed to the output port.
   - Diagnostics inside of the accelerator enclosure. The seed beam may be diverted outside of the beamline for various diagnostics (e.g. electro-optic electron beam profiler, THz output profiler). These applications are covered in the “SDL Drive and Seed Laser System” SOP.

goggles: use e.g. Kentek GBM 64
controls: neutral density filters located on seed table may be inserted in and retracted from the beam through the control system. Power attenuator located in laser room. Beam shutter (located

in the laser room) may be controlled from the control area, the laser room, or the gun hutch. A 633 nm cw alignment beam is permanently set up to be co-aligned with this beam.
hazard controls: beam enclosure. beam in the experimental area is enclosed and terminated, except for rare alignments. The beam in the 2 diagnostic enclosures is also enclosed. Procedures and posting requirements for access to the enclosures described below (an interlocked enclosure for the diagnostic beams will be in place by January 2004)

2) FEL output (fundamental)
purpose: supplied to user experiments and diagnostics
output: 200 μJ max, 266 +-10 nm, 0.2-1psec pulse width, 2.5 Hz
beam paths: beam enclosure. beam in the experimental area is enclosed and terminated, except for rare alignments. The beam in the 2 diagnostic enclosures is also enclosed. Procedures and posting requirements for access to the enclosures described below (an interlocked enclosure for the diagnostic beams will be in place by January 2004)
goggles: use e.g. Kentek GBM 64
controls: controlled through electron beam and seed beam parameters.
hazard controls: beam enclosure. beam in the experimental area is enclosed and terminated. The beam in the 2 diagnostic enclosures is also enclosed, with procedures and posting requirements for access to the enclosures described below (an interlocked enclosure will be in place by January 2003)

3) FEL output (harmonics)
purpose: supplied to user experiments
output: 89 and 133 nm, 0.2-1psec, 1 μJ, 2.5 Hz
beam paths: originates in the radiator (see diagram) and propagates to the experimental chamber (enclosed path)
goggles: N.A (absorbed in air, and no exposure possible).
controls: controlled through electron beam and seed beam parameters.
hazard controls: enclosed beam in vacuum.

☐ **Cryogen Use: None**

☐ **Chemicals & Compressed Gasses**

- Solvents (methanol, acetone) used for cleaning optics, kept in 1-4 liter quantities . Stored with secondary containment.

☐ **Electrical Hazards**

There are no electrical hazards associated directly with the DUVFEL output. Users and operators should of course be aware that this is located in an accelerator laboratory however, and there are electrical hazards associated with that, which are documented in the accelerator standard operating procedures. A user at the end station will not encounter these, but should be aware that hazards exist elsewhere in the building.

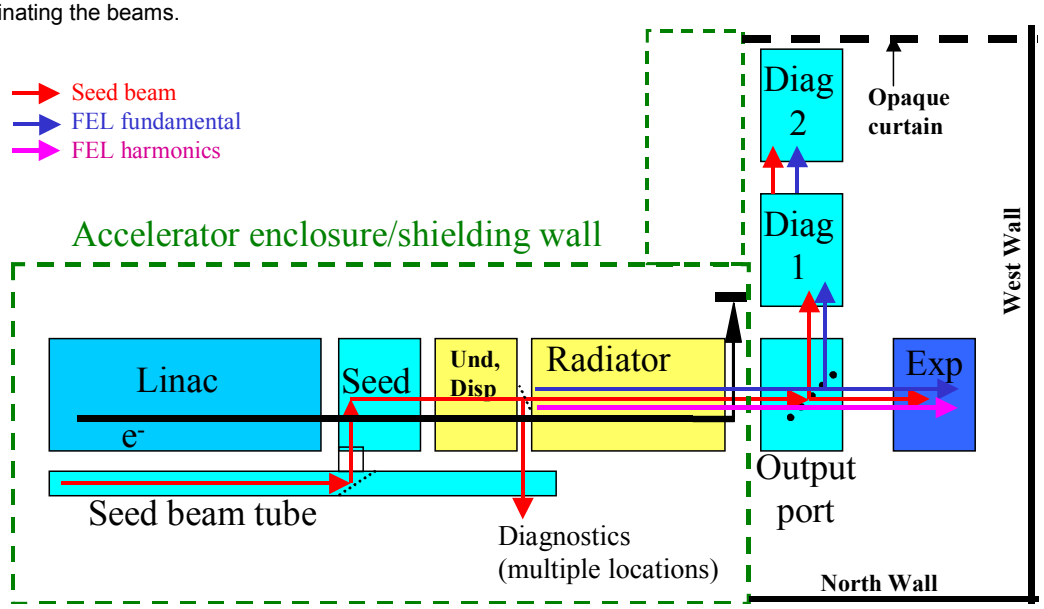
☐ **Other Special Equipment**

Standard Diagnostic equipment: oscilloscopes, photodetectors, power meters, autocorrelators, spectrum analyzers, monochromators, streak camera, PC-based data acquisition system, cameras, monitors.

With all optical diagnostics, the operator must exercise special care when working with the optical beams inside the device, as the beams may pose a hazard when misaligned or even during normal operation

(e.g. the moving reflection inside a scanning autocorrelator). Read the safety section of the device's manual and wear protective eyewear.(see charts below for proper eyewear for given wavelengths)

Laser System Configuration:
As shown in the diagram below, the seed beam (source #1) propagates in an enclosed pipe parallel to the accelerator on the latter's north side. West of the linac, the beam is deflected into an optical enclosure (box labeled Seed in diagram), where several optics are positioned to couple the beam into the accelerator. In FEL operation, the seed beam interacts with the electron beam in a short undulator (Und, Disp box) and then propagates to the end of the vacuum line. The electron bunch propagates on through the dispersive section and radiator, and then is deflected by a dipole magnet. The electorn bunch produces the FEL output fundamental and harmonics (sources #2 and #3) inside the radiator section All three sources: seed, fundamental, and harmonics are coupled out of the accelerator enclosure via a periscope comprising 2 mirrors, normally of Silicon Carbide. These steer the beams into the experimental chamber, where they terminate. An insertable mirror located in the output port can divert all or part of the seed and fundamental to the diagnostic enclosures (Diag1 and Diag2), via enclosed beam tubes. Instrumentation inside these enclosures is used to analyze the output before terminating the beams.



DEVELOP CONTROLS
IDENTIFY ES&H STANDARDS

ENGINEERING CONTROLS

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

Engineering Controls Description:

At present, all beam paths are enclosed. Inadvertent access to the experimental chamber would vent the accelerator and terminate the beam before personnel exposure would be possible. At present access to the enclosures Diag 1 & 2 will not terminate the beam. The area containing these enclosures is to be blocked off by an opaque curtain, with access to be governed by the administrative procedures below on a temporary basis. Those enclosures will be replaced by January 2004 with an interlocked enclosure.

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☐ Operating Limits

Administrative Controls Description:

- The area around the experimental enclosures and the diagnostic enclosures 1 and 2 will be posted with the “Danger” laser warning sign as follows:
  - sign on shielding wall above output port
  - signs on top panel and front panel of enclosures Diag 1 and Diag 2
  - sign on transport tubes between enclosures
- Diag1 and Diag2 enclosures are to remain closed and may only be accessed by a Qualified Laser Operator.

When laser radiation is reaching the DUVFEL output port and entering enclosures Diag1 or Diag2, or if it is entering the experimental area and not being terminated (as for a rare alignment), the following procedures will be followed

- The opaque curtain south of the diagnostic enclosures is to be drawn from the shielding wall to the west wall of the building. The area bounded by the curtain and the north, west, and shielding walls will optically enclose the endstation area on four sides, and constitute a Temporary Laser Controlled Area (TLCA). The LSO must approve any change in the TLCA, and designate the nominal hazard zone (NHZ)
- Access to the TLCA is permitted only to qualified operators and users who have completed Laser Safety Training. Of those, only persons who have received the laser medical surveillance and

have completed the system specific training may work within the diagnostic enclosures manipulating beams. The others may remain in the area provided they are wearing protective eyewear.
- Access is for servicing the seed beams and output beams of the DUVFEL. This may be done when measurements need to be done or the output configuration altered in the normal course of daily operations.
- The entrance to the NHZ will be posted with the “Danger” laser warning sign.

Users accessing the enclosures Diag 1 or Diag 2 are reminded that, under safe operating procedures, there is no reason that any beam should leave the confines of the enclosures. Only the top covers need to be removed when the beam is on under normal operations, the optics are prealigned with a HeNe laser such that all paths are confined, and no user adjustment should alter that fact. It is worth reiterating here, however, a few common sense principles of working with exposed beams:
- always wear eye protection, and make sure that others in the hazard zone are wearing them.
- make sure that reflective jewelry/badges/clothing that might intercept the beam is removed. For example, watches, rings, bracelets, pendulous necklaces. Note that ID badges should not be worn around the neck: they can drop into the beam when you lean over.
- always make all adjustments at the lowest possible intensity
- never insert reflective surfaces into the beam. When inserting an optic, block the beam upstream of the intended insertion, then secure the optic stably in the desired location and orientation, then unblock the beam. When removing an optic, block the beam upstream of the optic before removing it, and be certain of where the new beam path will be with the optic removed..
- always minimize the number of personnel within the hazard zone, and be sure that those who do remain in the area are aware of what you are doing

Comment: Here is where we need to define the, “service operation” for which we will use the “Temporary Laser Controlled Area” . We need statements to describe:

-What specific operations require work with open beams?
- How often these operations are required?

CONFIGURATION CONTROL

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 DUV FEL SOP Attachment #2

PERSONAL PROTECTIVE EQUIPMENT

☒ Eye Wear ☐ Skin Protection

No.	System Name							
1	Seed Beam							
2	DUVFEL output (fundamental)							
3	DUVFEL output (harmonics)							
Laser & Eyewear Parameters								
	ANSI Z136.1 Class					I	IIIb	IIIb
	Wavelength [nm]					~89, 133	~266	~800
	Intra-Beam OD Required							
	single shot					NA	1	5
	0.25 s					NA	1(single shot)	1
	10 s					NA	2	2

Comment: We need to define here which glasses to use for these lasers. I deleted the larger chart that you had as it pertained to other laser systems. Here we need to tell the laser operator which glasses to use for these three systems.

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 BNL World Wide Web based training course (BNL course #TQ-LASER).

See attached training checklist (SDL SOP Attachment #1)

All laser safety training must be repeated every two years.

MEDICAL SURVEILLANCE

Operators of ANSI Class 3b and 4 laser systems must complete a baseline medical eye examination prior to laser system operation. Any qualified ophthalmologist may complete this exam. BNL has arranged for this service from the following local physicians:

Dr. Charles Rothberg 331 East Main St. Patchogue, NY 11772	The Ophthalmic Center Dr. Basilice 3400 Nesconset Highway East Setauket, NY 11733	East End Eye Associates Dr. Sherin 669 Whiskey Road Ridge, NY 11961
631 758-5300 $65 per exam	631 751-2020 $60 per exam	631 369-0777 $125 per exam

Personnel using physicians other than those listed must have their examination records forwarded to the BNL Occupational Medicine Clinic.

FEEDBACK AND IMPROVEMENT

Comments and suggestions for improvement should be directed to BNL-Laser Safety Officer, Chris Weilandics (X2593; weil@bnl.gov).

LASER USER QUALIFICATION

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.

Each Qualified Laser Operator must sign below to confirm the he/she has completed the training and surveillance indicated in each column and that the dates indicated for the, “Basic Laser Training” and the, “Medical Surveillance” are accurate and may be found in the BNL BTMS database.

Qualified Laser Operators:

Basic Laser Training	Job-Specific Training	Medical Surveillance	Printed Name	Signature	Owner/Oper. Initial/date
9/12/03	10/27/03	4/9/02	Zilu Wu		
5/21/03	10/27/03	5/25/01	Henrik Loos		
10/08/02	10/27/03	11/13/02	Yuzhen Shen		
9/24/03	10/27/03	9/24/93	Brian Sheehy		
7/31/03	10/27/03	2/25/97	Adnan Doyuran		
7/25/02	10/27/03	5/15/00	Timur Shaftan		
5/3/02	10/27/03	8/14/98	Li Hua Yu		
10/2/03	10/27/03	7/16/96	Xijie Wang		
	10/27/03		James Murphy		

Comment: All the dates in the “Basic Laser Training” and “Medical Surveillance” columns must be in the BTMS database. When the Qualified Laser Operator signs this, he/she affirms that the dates are accurate and in the database.

	10/27/03		James Rose		
	10/27/03		Jonathan Neumann		
7/9/02	10/27/03		Wen Li		
	10/27/03		Arthur Suits		
	10/27/03		Pooran Singh		
	10/27/03		Joe Greco		

DUV FEL SOP Attachment #1

Laser Operator for the DUVFEL Output Training Certification Checklist

Completion of the items on this checklist and the signature of an authorized trainer will constitute the record of certification for an individual to be a qualified operator of the Laser System.

Safety Requirements:

- ☐ 1. Read appropriate safety documentation. This includes the material in the SBMS Laser subject area, and the SDL SBMS Laser Standard Operating Procedures (SOP). It also includes any information specific to a device the operator is working on (e.g safety sections of manuals to lasers, test, and diagnostic equipment). It is the operators responsibility to learn the published safety procedures for any equipment he undertakes to use.
- ☐ 2. Take required BNL eye examination
- ☐ 3. Complete Laser Safety Awareness Training Course, Compressed Gas Course, and Basic Electrical Safety course.
- ☐ 4. Eye protection required.
- ☐ 5. Insure that Controlled area is properly posted and light curtain is closed.

Minimum Systems Knowledge requirements for qualified operators (both levels). A detailed description of the current system start-up and alignment procedures for basic operation is given in the SOP. Since the SDL is an experimental facility, the details of the SOP procedure may change. . The procedures listed there are effectively the present implementation of the tasks/skills listed below and required of a laser operator

☐ 2. Understand procedures for starting/stopping beam
  - o seed laser shutter control at control desk or in laser room
  - o retractable mirror in the FEL output port that steers the beam to the diagnostics

☐ 3. Understand that there are two beams coming out of the FEL: residual seed beam also reaches the diagnostic table. This is an invisible IR beam, which may be seen with an IR detector card or the IR viewer. USERS SHOULD BE AWARE THAT THIS BEAM MAY BE PRESENT EVEN WHEN FEL OUTPUT IS NOT. It may be blocked with the laser shutter.

☐ 4. Understand the principles of safe alignment (in the Standard Operating Procedure). In particular, users should note the proper use of flip-up mirrors, which are used on the diagnostic table. Before flipping a mirror in or out of the beam, block the beam upstream of the flipper first.

☐ 5. Understand the basic beam path layout to monochromator and energy detector, and how this prealigned with the Helium Neon laser on the diagnostic table.

Operator Duties:

☐ 1. Perform beam alignments into diagnostics and make measurements

☐ 2. Insure that light is properly terminated.

☐ 3. Shut down any part of the facility within their area of control which may present a safety hazard until that hazard has been removed.

Trainer: _____
(print name) (signature)

Trainee: _____
(print name) (signature)

Date: _____

SDL FEL SOP Attachment #2

DUV FEL Configuration Control Checklist

- Beam terminated in Experimental Chamber
- Beam Tubes from output port to Diag1 in place
- Beam tube from Diag1 to Diag2 in place, or beam terminated in Diag1
- Diag1 and Diag2 enclosures intact
- Opaque curtain blocks beams below 8 feet at and beyond the boundary of the nominal hazard zone.

A completed checklist must be posted at the laser location.

This checklist must be exercised whenever there has been a system modification, extended shutdown, or change of operations.

Completed by:

(Printed Name) (Signature) (Date)

Revision Review Log