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: Laser calibration system for the STAR TPC and FTPC
Location: Bldg 1006

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: See Page 11 for Signatures

Name: Alexei Lebedev *Signature:* *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.

Chris Weilandics		05.26.01
BNL LSO printed name	*Signature*	*Date*
Asher Etkin		05.26.01
ES&H Coordinator printed name	*Signature*	*Date*

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

ANALYZE THE LASER SYSTEM HAZARDS

Hazard analysis requires information about the laser system characteristics and the configuration of the beam distribution system.

LASER SYSTEM CHARACTERISTICS

Laser Type	Wavelengths, nm	ANSI Class	Maximum Power of Energy/Pulse	Pulse Length	Repetition Rate
Spectra Physics, Nd:YAG, model GCR-130-10 , s/n 118, 1994	1064, 532, 266	4	290mJ@1064 30 mJ @266nm	5-8 ns	10Hz
Spectra Physics, Nd:YAG, model GCR-150-10, s/n 1367G, 1997	1064, 532, 266	4	600mJ@1064 50 mJ@266nm	5-8 ns	10 Hz
Uniphase, He-Ne, Model 155SL-1, s/n 301114	632	2	5 mW		CW

This system is using only 266 nm, other harmonics such as 1064 nm and 532 nm are used only by service engineer to check laser productivity and specifications. These harmonics are contained in beam dump load, supplied by Spectra Physics.

☒ **Electrical Hazards**

For Spectra Physics models both laser head and power supply contain electrical circuits operating at lethal voltage (~2kV) and high current levels. Only those trained in high voltage, high current electronics and who understand the circuitry of the GCR could service and repair the laser.

Even though both lasers are not under warranty from Spectra-Physics, laser component repairs such as laser head and power supply shall be provided only the by Spectra-Physics representatives. For this repair a controlled laser area shall be implemented.

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)*.

STAR TPC and FTPC laser calibration system, which is integrated into the STAR detector currently located in Bldg. 1006. The calibration of the TPC and FTPC is accomplished by providing ionization tracks in their volume. There are ~500 narrow ultraviolet laser (UV) beams in the TPC volume and ~15 narrow ultraviolet laser beams in the FTPC volume. The produced ionization paths simulate straight tracks whose position is known with ~200 microns accuracy. The TPC and FTPCs share two class IV lasers, installed on the south side of the STAR magnet. The internal laser system contains a complete Nd:YAG laser with 1064 nm infrared (IR) output beam, which is transformed into 266 nm UV beam via harmonic doublers, one half-wave plate, a telescope and a Poisson ball. These elements define the wide laser beam and Poisson line. The Poisson line is utilized as a straight thin reference beam for installation and adjustment procedure of the optical elements. The set of optics for both TPC and FTPC includes entrance mirrors, corner mirrors, prisms and small rods with 1 mm mirrors. A flipper mirror allows one to direct the laser beam to the TPC or FTPC. Alignment and monitoring of the laser beam position is provided by the set of multi axis motorized mirrors and CCD cameras via remote control on a PC. Start and stop procedures for lasers are managed locally through control boxes or remotely from STAR control room by computer via Slow Control window, if all interlocks are in place.

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

Brookhaven National Laboratory Environment Safety and Health Standard: 1.5.3 INTERLOCK SAFETY FOR PROTECTION OF PERSONNEL
Because these lasers provided a very high output power in IR and UV region and classified as CLASS IV Laser a set of engineering and administrative procedures were implemented for this system.

ENGINEERING CONTROLS

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

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. **Attach a copy of the design review documentation and a written testing protocol. Attach or keep elsewhere any completed interlock testing checklists to document the testing history.**

Engineering Controls Description:

The STAR laser system is operated enclosed laser beams, during routine operation. Engineering approach to this mode is to entirely enclose all laser heads and all possible of laser beam paths to the optics and detectors. Laser head and initial optics are enclosed into big aluminum box with removable covers secured by screws. In Addition a steel rope with a lock is installed at each laser box. After the laser head the beam is directed to the TPC or to the FTPC and split inside these detectors into thin beams. All laser beams and fanout optics are enclosed in pipes and aluminum boxes. All connections between boxes and pipes are made with screws and clamps. To open these connections a special tool is necessary. This envelope structure remains solid and stable while TPC is in operational. This envelope structure allows simultaneously running the laser system and monitoring the TPC performance while electronics is repaired on the TPC face. Commercial beam stops from Spectra Physics (model BD-5) are installed at the exits of the laser head to absorb unused infrared and green harmonics, generated by doubling crystals. To direct the UV beam from laser output to the TPC we use 4 spectral line mirrors, designed for 266 nm, these mirrors completely eliminate IR and green harmonics from UV. Operation of this mode is completely safe, because all optics and lasers are enclosed.
For laser service and optics replacement in the laser system a mode with open laser beam requires a working laser controlled area. To provide a safe laser operation UV opaque fire resistant curtains are installed to provide a completely closed area. It would be used around the laser only in case of laser service. These curtains will cover entirely the east and west faces of STAR detector. It is very unlikely to install these curtains again, but they are ready at all times. For the laser service a smaller curtain is used to define a controlled area around the lasers themselves. Curtains are installed with a folding entrance to prevent laser beam escape from this area. Near the curtain area posts with red rope and warning labels are installed. Near the entrance a stand with warning light is installed. On this stand an infrared (IR) beam interlock is installed to prevent any unauthorized entrance into laser area with the laser operational. A More detailed description of interlock system is presented in attachment 1.

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 (SOP) are required for laser system operation, alignment, and maintenance. The SOPs need only contain the steps necessary to perform these tasks and identify when and where posting and personal protective equipment is required. SOPs must be approved by the BNL Laser Safety Officer and should be kept with this program documentation.

Administrative Controls Description:

For normal routine operation, lasers are enclosed with aluminum boxes, pipes and laser beam optics enclosures. Standard warning labels approved by RHIC Safety management and the BNL-LSO are used. Additional warning labels, containing information about lasers, power, output energy, etc are installed on boxes with the laser head on both sides of STAR detector. Also a list of contact persons is posted on laser box. A steel rope with locks prevents unauthorized access to these boxes.

Alignment and service of laser with open beam requires additional administrative precautions. A temporary laser controlled area is created near the laser, with shielding, interlocks and warning lights. Additionally to these measures several stands with red rope and warning labels are installed defining the laser control area.

Prior to energizing the laser under normal conditions the operator should make a visual inspection of the laser housing and the transfer tube from the lasers to TPC an FTPC.

Prior to energizing the laser under alignment conditions the operator should:

1.Set up the warning signs around the tent area.

2. Verify that the integrity of the tent and verify that it is fully closed.
3. Illuminate the laser warning sign at the entrance to the tent.
2. Check the IR interlock at the entrance to the tent, make a note in laser log book.

Procedures

Normal Operations: (any trained laser operator may operate the system)

1. Get laser ignition key from the STAR key cabinet in the trailer.
2. Check the integrity of the laser enclosure and the beam path to the TPC and the FTPC.
3. Check the flammable gas interlock
4. Put key into laser ignition and turn.
5. Energize lasers through the SLOW CONTROL window in computer in control room.
6. Verify alignment of lasers using electronic sensors.
7. Fine tune alignment of the laser beam with the remote actuators.

During RHIC operation and when access to Wide Angle Hall with STAR detector is prohibited, laser operation is only possible through Slow Control window from the Control room. At this point any trained Detector Operator can operate the laser without laser specific training.

Alignment and Maintenance Procedures:

1. Set up laser warning signs
2. Set up the laser curtain and verify that all direct lines of sight to the laser beams are blocked.
3. Set out the illuminated laser-in-use sign at the access point to the tent.
4. Set out the IR beam interlock at the access point.
5. Get the laser ignition key from the STAR key cabinet in the trailer.
6. Remove all jewelry and watches.
7. Check and put on laser safety goggles.
8. Insert laser ignition key and energize the laser.

Beyond this step, procedures are specific for the given task. The procedure for the initial alignment is outlined here: First, the steering EXIT mirror at the exit of the laser housing is adjusted via remote piezoelectric drivers to direct a beam to the entrance mirror in box D. A special target-cross is installed in face of the entrance mirror to ease alignment. The steering mirror is manually adjusted to make the target-cross and the Poisson coincide. Once this process is complete, a wide laser beam (~25 mm diameter) is steered by the KNEE mirror to ½" mirrors to divide wide beam into 3 beams ~8 mm diameter. Each small beam is directed to designated TPC and FTPC corner mirrors. After this each small beam shines on a small ceramic rod with five 1 mm mirrors. These mirrors create thin laser beams to calibrate TPC and FTPC. After this procedure the position of wide and small beams is fixed on CCD cameras and in the future, realignment will be performed only by piezo drivers on EXIT and KNEE mirrors. After the first alignment all laser beams on the TPC and FTPC wheel are enclosed into Al pipes. Additional details may be found in an available scientific summary of this procedure (see *Laser Calibration System for the STAR TPC*, M. Alyushin *et al*. IEEE Nuclear Science Symposium, Anaheim CA, Nov 2-9, 1996, N27-33).

<u>Maintanance of laser system</u>

Specially trained and/or certified laboratory personnel will maintain the laser equipment. All relief devices, safety interlocks, alarms, and other hazard prevention devices will be maintained, calibrated and tested for functionality on a regular basis in accordance with standard industrial practices and recommendations of the manufacturers.

CONFIGURATION CONTROL

Prepare and attach a checklist to be used for configuration control of any protective housings, beam stops, beam enclosures, and any critical optics *(mirrors or lenses that could misdirect the beam and result in personnel hazard)*. Include entries 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.

Prior to initial operation after an extended shutdown the laser and beam transport enclosures shall be inspected for integrity by a trained operator in addition after the a pole piece has been removed the associated enclosures shall be inspected prior to inserting the pole piece.

PERSONAL PROTECTIVE EQUIPMENT

☒ Eye Wear ☐ Skin Protection

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.
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.

The most common hazard with this class 4 laser is loss of vision due to retinal(1064nm) and corneal(266nm) damage. The beams used in this system are invisible and thus one would have no blink response were a beam to be incident on the eye. For this reason during operation with open beam safety glasses shall be used at the times.

EYE WEAR SPECIFICATIONS

Laser System Eyewear Identification	Wavelengths	Intra-beam Optical Density	Diffuse Optical Density
UVEX	1060 nm	OD 5+ @1060nm	N/A
GPT	266 nm	OD 15+ @332 nm	N/A

EYE WEAR REQUIREMENTS				
Laser System Eyewear Identification	Wavelengths	Intra-beam Optical Density	Diffuse Optical Density	NHZ (meters)
Spectra Physics, Nd:YAG, model GCR-130-10	1064 nm	OD 5.66 (10 sec.)	OD 2.61 (600 sec.)	4.03 meters
	266 nm	*OD 3.3 (10 sec.)	OD 1.7 (600 sec.)	1.4 meters
Spectra Physics, Nd:YAG, model GCR-150-10	1064 nm	OD 6 (10 sec.)	OD 2.9 (600 sec.)	5.8 meters
	266 nm	*OD 3.52 (10 sec.)	OD 1.9 (600 sec.)	1.8 meters
Uniphase, He-Ne	Uniphase, He-Ne	NA	NA	

266 nm direct ODs are based on 8 mm beam diameter(0.5 cm^2)

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.

STAR laser system is using only 2 wavelengths- 1064 nm during laser calibration and service and 266 nm during routine laser operation. Green harmonic with wavelength 532 nm totally absorbed in beam dump, installed on laser head. During laser service with IR beam only a special diffuse screen or photograph paper are used to align the resonator. Construction of laser box prevents any possibility to have direct IR beam into human eye. From this we could conclude a safe operation with IR beam.
For the UV beam with diameter ~8 mm we have a maximum 60 mJ pulse. At the same time we have much more strong attenuation goggles with OD=+15.

The following are the optical density requirements for the laser operation; they are based on the maximum stated outputs for the 1064nm and 266nm beams. The direct 1064nm beam is not accessed by the user.

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 #HP-IND-011).

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
  - Review of this program documentation
  - Review of SOPs

All laser safety training must be repeated every two years.

This is not really required

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. For training and medical surveillance, enter the date of completion.

Qualified Laser Operators:

Basic Laser Training	Job-Specific Training *	Medical Surveillance	Printed Name	Signature	Owner/Oper. Initial/date
		12/11/1997	Alexei Lebedev, 21605		

* See attached "Laser System-Specific Training Checklist"

See Page 12 for Signatures

LASER SYSTEM-SPECIFIC TRAINING CHECKLIST

Laser User:	
Laser Owner:	
Laser System:	

Topic	User Signature / Date	Owner Signature / Date
General Laser Safety • Laser classifications • Laser hazards • Maximum permissible exposure • Good practice in the lab		
LCA Interlock Instruction • Configuration • Operation		
Description of Laser Output Characteristics • Wavelength • Pulse energy • Average power		
Associated electrical hazards • Power supply • PMT detectors		
Normal Operation • Power on/off • Shutter operation • Normal experimental configuration • Nominal hazard zone		
Non-Normal Operation* • Gross alignment • Troubleshooting		

* *Only those users who have completed the Non-Normal Operation portion of the laser-specific training may perform gross alignment procedures as defined in the Standard Operating Procedure.*

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Location: Bldg 1006

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: Alexei Lebedev *Signature:* [signature] *Date:* 10/31/03

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	[signature]	10/31/03
BNL LSO printed name	*Signature*	*Date*
Asher Etkin	[signature]	10-31-2003
ES&H Coordinator printed name	*Signature*	*Date*

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03.11.02	10.31.03	12/11/1997	Alexei Lebedev, 21605	[signature]	A. L.

* See attached "Laser System-Specific Training Checklist"