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: **Soft Matter Physics Group, Optical Microscopy System for Organic Thin Films**

Location: **Bldg 510, the optics lab (inner room) inside Room 2-106 (CMPMSD space)**

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: **Masafumi Fukuto** *Signature:* Masafumi Fukuto *Date:* 3/17/09

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.

Jack Preses	Jack Preses	3/17/09
BNL LSO printed name	*Signature*	*Date*
C. Weilandics	C. Weilandics	3/25/09
BNL ALSO printed name	*Signature*	*Date*
[illegible]	[illegible]	3/17/09
Department ES&H Approval printed name		*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
Argon-Ion (Air-cooled; Spectra-Physics, Model: 177-G12-FBR)	**488 nm**	**IIIb**	New tube, without fiber coupling: **200 mW/CW** New tube, with fiber coupling: **140 mW/CW**	N/A	N/A
Diode	**670 nm**	**3R**	**1 mW/CW**	N/A	N/A

☐ **Cryogen Use**
Describe type, quantity, and use.
NOT used.

☒ **Chemicals & Compressed Gasses**
Describe type, quantity, and use.

- **Chemical use is limited to sample preparation and handling, which are covered under the Experimental Safety Review PM2008-74 (Title: "Soft Matter Chemical Procedures and Instrumentation").**

- **Compressed air is used to activate the vibration isolators in the optical table posts. (For proper set-up and operation of the vibration isolation control, consult the "*General Instructions*" booklet for TMC MICRO-g Vibration Isolation Systems.) The compressed air is supplied through Polyflow tubing that is fixed to ceiling and walls and is connected to a compressed air cylinder located outside Rm 2-106. The gas cylinder shall be equipped with a regulator and shall be fastened to the wall mount in the hallway on the north side of Rm 2-106 (the wall opposite to the men's room). The supply line pressure shall not exceed 100 psi. When the vibration isolator is not in use for an extended period of time, close the main valve of the cylinder and depressurize the gas line.**

☒ **Electrical Hazards**

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

The power supply (Spectra-Physics, Model 277-GA01) is external to the laser head and is as supplied by the manufacturer. The input is rated at 220 VAC, 60 Hz, 16 A max. The minimum output is 70 VDC at 4.0 A, and the maximum output is 220 VDC at 12.0 A. Potentially lethal voltage levels exist inside the power supply.

☒ **Other Special Equipment**

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

* **Nikon optical microscope**

The Nikon 80i microscope is used to inspect samples with small features. The microscope can operate in either transmission or reflection mode and therefore requires 3 light sources, two halogen lamps and one mercury lamp. All three lamps came as part of the microscope unit and are as provided by the supplier. The mercury lamp is used for fluorescence microscopy and its spectrum extends to UV range. The UV part of the spectrum is attenuated by filters and does not pose hazard to eyes. An absorbent visor is also installed to block off possible stray UV rays reflected by the sample. However, the lamps do generate a lot of heat and the microscope should not be covered until the lamp houses cool down to room temperature. In general the halogen lamp should be turned off when not in active use to prolong the lamp life. In contrast, the mercury lamp should be left on during short intervals between observations, since frequently turning it on and off reduces its lifetime.

* **CCD camera**

Captures images of organic thin films; the image is formed by the light that is either fluoresced or reflected by the film. The power should be kept OFF during sample handling and turned ON only during the measurement. The unit should be properly encased during operation; never operate with its cover off. Be careful to avoid saturation.

* **Sample cells**

Organic thin films to be imaged are formed at various interfaces. Preparation and control of these films require different sample cells depending on the type of interfaces:

- **Langmuir troughs for films at liquid/vapor interfaces: There are a few instruments of this type in our laboratory. Each of them contains i) a shallow container ("trough") that holds water or an aqueous subphase, on the surface of which a thin organic film is spread; ii) a moveable barrier that is computer-controlled to vary the area of the film-coated surface; iii) a surface tension balance; and iv) a cooling plate underneath the trough for temperature control.**
- **Flow cells for films at liquid/solid interfaces: A sealed cell contains a substrate and is filled with water or an aqueous solution.**
- **Sample cells for films at solid/vapor interfaces (film-coated substrates): A sealed cell contains a substrate and a liquid reservoir and is filled with the vapor of the liquid. The temperature and/or the vapor pressure are controlled.**

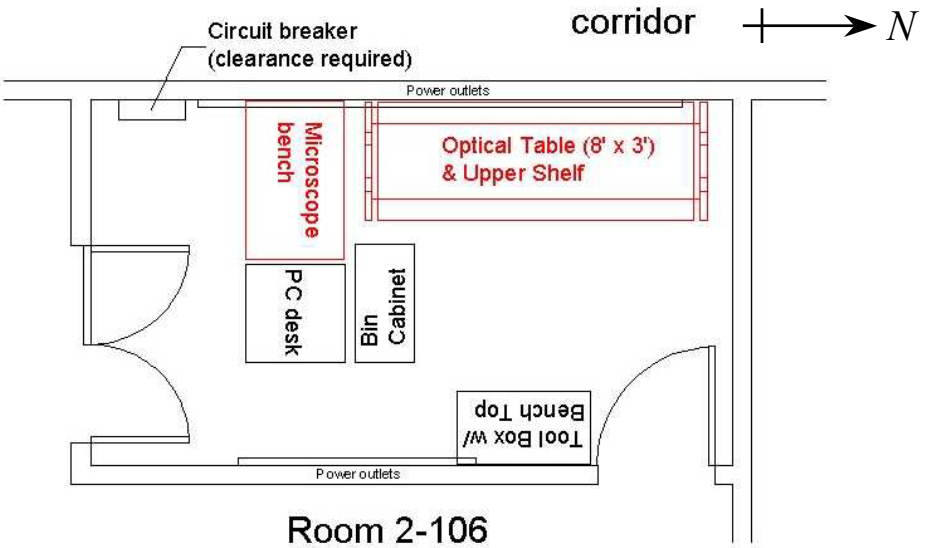
Handling of the sample presents a potential risk for water spills. With the exception of sample cells and the CCD camera, DO NOT place any electrical/electronic devices, controllers or power supplies close to (within a foot of) the sample area on the optical table or on the microscope stage, and make sure that all such devices are properly encased/enclosed.

* **Neslab water circulators/chillers [NOT for cooling the laser head]**

Used to control the temperature of the Langmuir troughs; see the sample cell description above. The circulator unit must be placed on the floor. Make sure that there are no leaks in the plumbing/tubing.

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*).

OPTICS LAB LAYOUT



SYSTEM CONTROLS

Keys:

- **A key switch on the power supply unit (Spectra-Physics, 277-GA01) turns on/off the power supply to the laser head.**

Switch Panels:

- **Front panel of the power supply unit (Spectra-Physics, 277-GA01), as provided by the manufacturer. One switch is for turning on/off the AC power and the cooling fans on the power supply and the laser head. The other is the key switch for turning on/off the laser. See *Spectra-Physics Model 177-Series Laser Systems User's Manual.***

- **Remote control module (Spectra-Physics, 377-G10), as provided by the manufacturer. The controller is equipped with power INTERLOCK jumper that needs to be shorted for laser operation. The unit allows the user to turn on/off the laser and control laser output either via laser output power or via plasma tube current. See *Spectra-Physics Model 177-Series Laser Systems User's Manual.***

- **Black "Interlock Box". This unit controls i) shorting/opening of the power INTERLOCK jumper on the remote controller, ii) illumination of the warning signs outside the**

entrances, and iii) opening/closing of the laser-head shutter, which is interlocked with the entrance doors. See the descriptions in Engineering Control section below and the interlock documentation.

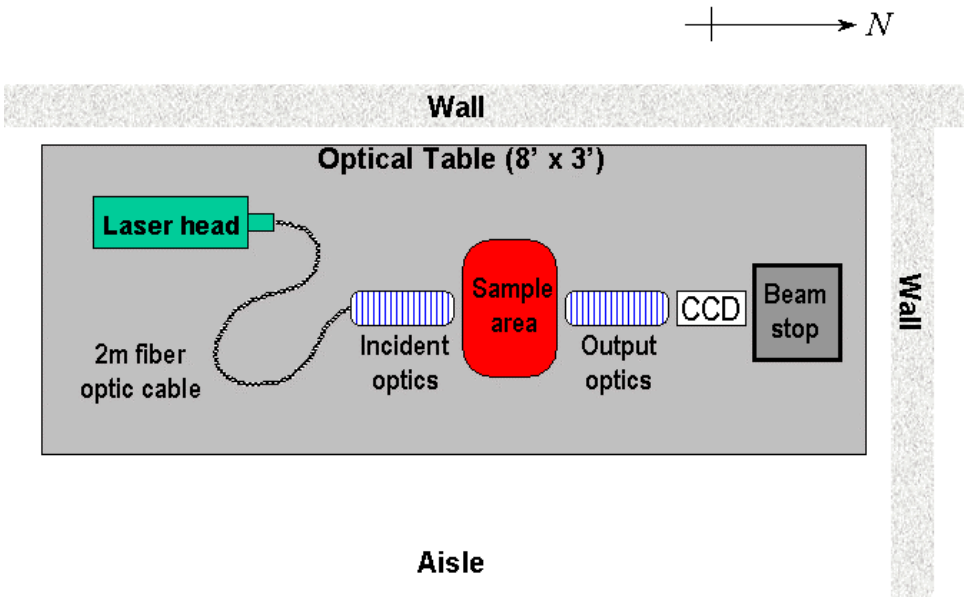
- **Black "Laser Shutter" box located on the outside wall near one of the two entrances. A push-button switch on this box allows a user to open the laser shutter from outside the room. See the descriptions in Engineering Control section below and the interlock documentation.**

<u>Computer Controls</u>:
NONE

<u>BEAM PATHS and OPTICS</u>

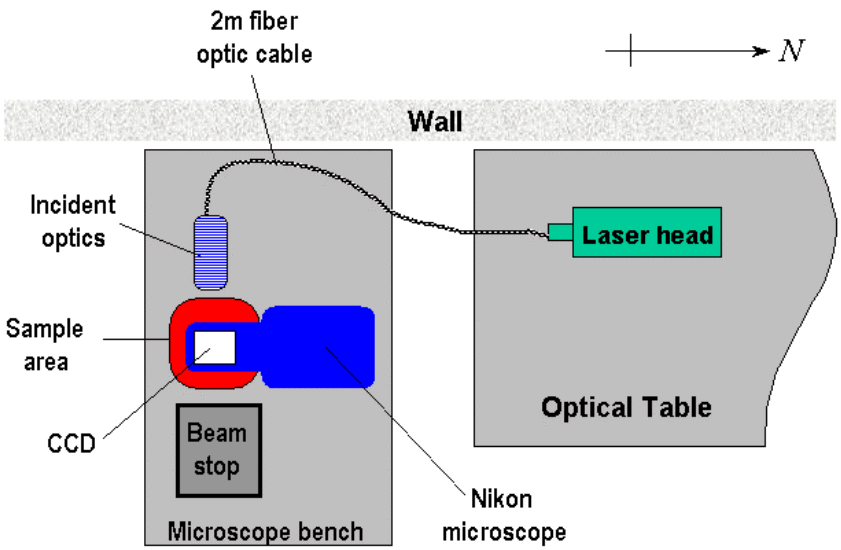
A given experimental setup shall conform to one of the following two general configurations:

Configuration 1: Experiments without Nikon microscope



- **Incident and output optics may contain any of the following: apertures, mirrors, lenses/objectives, polarizers, retardation plates, and dichroic filters.**
- **Output optics and CCD can be positioned <u>in any direction and orientation</u> around the sample area (the above figure shows one such example).**
- **Laser beams shall be actively terminated with the use of a beam stop and beam blocks.**
- **Under normal operation, laser beam shall remain on the optical table.**

Configuration 2: Experiments where laser is used in conjunction with Nikon microscope



- **Incident optics may contain any of the following: apertures, mirrors, lenses/objectives, polarizers, and retardation plates.**
- **NEVER direct the laser beam through/along the optical axis of the Nikon microscope. That is, the direct or specularly reflected laser beam is NOT allowed to enter the microscope objective. Only diffuse-scattered or fluorescence light is allowed to enter the microscope objective. [Any change to this rule requires a modification of the present SOP and a review and re-approval by the Laser Safety Officer.]**
- **Laser beams shall be actively terminated with the use of a beam stop and beam blocks.**
- **Under normal operation, laser beam shall remain on the optical table and the microscope bench.**

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

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 Stop:**

☒ **Activation Warning System:**

i) Red indicator lamp for the "MAIN" switch of the Interlock Box. Flipping the MAIN switch ON lights up the indicator and shorts the "INTERLOCK" jumper on the remote control module (Spectra-Physics 377-G10), which is necessary to allow the laser power to turn on. Thus, the glowing MAIN lamp indicates that the laser CAN BE turned on.

ii) "LASER ON" warning signs, located outside and above the two entrances to the room. These signs are illuminated also when the MAIN switch on the Interlock Box is turned ON, i.e., whenever the laser CAN BE powered on.

iii) RED power-on/emission indicator on the front panel of the laser power supply unit (Spectra-Physics 277-GA01). The indicator glows when AC power is applied to the system, the DC regulators are powered up, and emission is present or imminent.

iv) Display on the remote control module (Spectra-Physics 377-G10) indicates either the laser output power or the plasma tube current, depending on the setting of the "POWER/CURRENT DISPLAY" switch.

☒ **Key Controls: Located on the laser power supply unit (Spectra-Physics 277-GA01).**

☒ **Other Interlocks:**

Laser-head shutter interlock. The safety shutter on the laser head (as supplied by the manufacturer) is mechanically coupled to a spring-loaded solenoid, whose activation is controlled by the Interlock Box, the "LASER SHUTTER" box located outside near one of the two entrances, and the limit switches on the entrance doors. If

i) the MAIN switch is ON, and
ii) the SHUTTER switch is at the "ENABLE" position, and
iii) all the doors are closed,

then,

a) pressing the SHUTTER "OPEN" push-button switch on the Interlock Box, or
b) pressing the push-button switch on the LASER SHUTTER box outside,

powers up the solenoid and opens the shutter. Whenever any one of the doors is opened, the power to the solenoid shuts off, and the shutter is closed by the springs. After the door is re-closed, the shutter remains closed; in order to reopen the shutter, one of the two push-button switches [a) or b) above] must

be pressed. The RED "SHUTTER OPEN" lamp on the Interlock Box and the RED lamp on the "LASER SHUTTER" box outside glow only if the shutter is physically open, by means of the magnetic switch located on the shutter coupling.

☒ **<u>Emission Delay</u>: 30 sec delay whenever following a hard reset on the laser power supply (i.e., after the filament current is turned off), including the opening of the "INTERLOCK" jumper on the remote control module (Spectra-Physics 377-G10). Note that this does not apply if the beam is turned off with the "DISCHARGE" switch on the remote controller, which turns off the plasma tube current but keeps the filament current on, so that there is no emission delay when the DISCHARGE switch is turned back on.**

☒ **<u>Other:</u>**

Protected laser-head housing. Although not interlocked, the housing of the laser head is an enclosed system and requires tools to disassemble and expose the inside. There is no cover that would just come off freely.

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: The entire space inside the optics lab room (the small room inside Room 2-106).**

☒ **Signs:**
- **i) Standard "DANGER" signs posted on the doors of the optics room.**
- **ii) "LASER ON" warning signs above the doors (also see the Engineering Control section above).**
- **iii) Signs posted on the doors of the optics room that indicate the next due date for the semi-annual interlock test and the fact that the user is not allowed to activate the laser if the interlock test is overdue.**

☒ **Labels: On the laser head (Spectra Physics 177-G12-FBR) and the power supply unit (277-GA01), as provided by the manufacturer.**

☒ **Operating Limits:**
Configuration 1: Experiments without Nikon microscope.
Under normal operating conditions [i.e., after the system is aligned], laser beams and the target must remain on the optical table.

Configuration 2: Experiments where laser is used in conjunction with Nikon microscope.
Under normal operating conditions [i.e., after the system is aligned], laser beams and the target must remain on the optical table and the microscope bench. The laser beam is used only to illuminate the sample or excite fluorescent probes in the sample. The direct or specularly reflected laser beam is NOT allowed to enter the microscope objective, and only diffuse-scattered or fluorescence light is allowed to enter the microscope objective.

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.

STANDARD OPERATING PROCEDURES

i) Normal Operations

- **Check to make sure that the semi-annual testing of the interlock system is up to date. If overdue, completion of the interlock checks is required before a user is allowed to use the laser.**
- **Before starting the laser, check to make sure that both of the two warning signs outside are illuminated with all four light bulbs lit (2 bulbs per sign). If a light bulb is burned out, have it replaced before proceeding.**
- **Before starting the laser, check to see that all the doors to the optics lab are closed.**
- **Laser power shall remain off and shutter closed during sample handling. Check to make sure that there is no water leak on the optical table or on the floor.**
- **Check to see that all the electrical devices other than the sample cell and the CCD camera are at least a foot away from the sample area.**
- **Check to make sure that all bending mirrors and other necessary optics are in place such that the intended optical paths will be followed by the laser beam.**
- **Laser shall be operated only by a trained user listed on the qualified laser user list.**
- **When laser is in use, only the listed users may enter the optics lab. Neither an untrained personnel nor a visitor is allowed in the room unless approved by the ES&H Coordinator or the Department Chair.**
- **The CCD camera shall not be exposed to room light or the laser beam while being energized.**
- **The space in front of the optical table shall not be blocked at any time.**
- **The laser beam shall be actively terminated with a beam stop at the end of its normal path and any possible alternate path(s).**
- **The laser beam should never be routed at normal eye level, typically heights between 1.3 and 2.0 m above the floor.**
- **Objects capable of specular reflections should be avoided on the optical table and on the user, *e.g.*, jewelry.**
- **When used in conjunction with the Nikon microscope, make sure that the laser beam will NOT go though/along the optical axis of the microscope; that is, the direct or specularly reflected laser beam is NOT allowed to enter the microscope objective.**

Only diffuse-scattered or fluorescence light is allowed to enter the microscope objective.

- **Turn on laser only after all steps above have been completed.**
- **Under normal operations (i.e., after alignment) where laser is used without the Nikon microscope, laser beams and the target must remain on the optical table.**
- **Under normal operations where laser is used in conjunction with the Nikon microscope, laser beams and the target must remain on the optical table and the microscope bench.**

ii) <u>Maintenance: General Alignment</u>

- **Attenuate the beam as much as possible, but to the extent that the beam is still visible through the safety glasses.**
- **All normal operating procedures shall be followed during alignment of the laser and the optical system.**
- **When used in conjunction with the Nikon microscope, make sure that the laser beam will NOT go though/along the optical axis of the microscope; that is, the direct or specularly reflected laser beam is NOT allowed to enter the microscope objective. Only diffuse-scattered or fluorescence light is allowed to enter the microscope objective. [Any change to this rule requires a modification of the present SOP and a review and re-approval by the Laser Safety Officer.]**
- **Any changes in optical configuration required for alignment but not for normal operations shall revert to the normal configuration when alignment operations are completed.**

iii) <u>Maintenance: Fiber-Optic Cable and Coupling</u>

- **Fiber assembly is pre-aligned at the factory but may require fine-tuning during initial installation and after normal plasma tube replacement (only via service). If so, follow the fiber alignment procedure detailed in Chapter 4, pages 4-4 to 4-5 of *Spectra-Physics Model 177-Series Laser Systems User's Manual*. The General Alignment procedures described above shall be followed during the fiber alignment.**
- **The optics at each end of the fiber-optic cable assembly are NOT user-serviceable. Do not attempt to clean or service any part of the fiber-optic cable assembly. If there is a reason to suspect that the optics have been contaminated or broken and that service may be required, the laser owner/operator shall contact the manufacturer.**

iv) <u>Maintenance: Laser System</u>

[Also see Chapter 2, page 2-3 of *Spectra-Physics Model 177-Series Laser Systems User's Manual*.] In order to maintain the compliance of the laser system with Center for Devices and Radiological Health (CDRH) regulations, the following need to be verified either annually or whenever the system has been subjected to adverse environmental conditions

(e.g., fire, flood, mechanical shock, spilled solvents). <u>Check the three items below together with the semi-annual testing of the interlock system</u> (see the interlock documentation):

- **Verify that removing the two-pin INTERLOCK jumper connector on the remote controller (Spectra-Physics 377-G10) prevents the laser operation.**
- **Verify that the power supply key must be in the ON position before the laser will start, and that it can only be removed when in the OFF position.**
- **Verify that the mechanical shutter on the laser head actually blocks exposure to laser radiation.**

The General Alignment procedures above shall be followed during these tests. If any of these tests fail, laser owner/operator shall contact Spectra-Physics Lasers service center.

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.

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***
Argon-Ion Max. 200 mW	**488 nm**	**2.3 (0.25 sec)**	**N/A**	**< 20 cm**	• **THORLABS "LG3" Laser Safety Glasses** • **KENTEK "UVEX" Eyewear UXK-ARG-A**

* 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 [T = 10^(-OD)]
THORLABS "LG3" Laser Safety Glasses (recommended for normal operation)	**190 – 449 nm** **450 – 532 nm**	**> 5** **> 6**
KENTEK "UVEX" Eyewear, UXK-ARG-A (good for alignment)	**190 – 380 nm** **488 – 515 nm** **10,600 nm**	**7** **2 – 3** **5**