BROOKHAVEN NATIONAL LABORATORY
LASER CONTROLLED AREA
STANDARD OPERATING PROCEDURE (SOP)

U2A Laser Systems

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*.

System description:
There are 4 lasers installed at beamline U2A for diamond anvil cell experiments:
Coherent Innova 90 Plus Argon Ion Laser (Class 4)
B&W Tek Diode Pumped Solid State Laser (Class 3A)
Spectral-Physics Diode Pumped Solid State Laser (Class 3B)
CrystaLaser Compact Solid State Laser (Class 3B)

Location:
All four lasers are located in the U2A beamline hutch of Building 725.

LINE MANAGEMENT RESPONSIBILITIES

The Owner/Operator(s) for these lasers 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: *Zhenxian Liu* *Signature:* *Date:* 9/16/2011

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) *C. Weilandics*	*Signature*	*Date*
Department ES&H Coordinator (printed name) *Lori Stiegler*	*Signature*	*Date*

APPLICABLE LASER OPERATIONS
☒ Operation ☐ Maintenance ☐ Service ☐ Specific Operation (specify)
OPERATION

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.)*	Wavelength(s) (nm)	ANSI Class	Maximum Power or Energy/Pulse (W or J)	Pulse Length (s)	Repe-tition Rate (Hz)	Beam Diameter (mm)
Argon ion	457.9 - 514.5	4	6.0	CW	N/A	2
Diode Pump Solid State (DPSS)	532	3A	0.02 (rated) 0.003 (measured)	CW	N/A	2
Diode Pump Solid State (DPSS)	532	3B	0.150	CW	N/A	0.32
Compact Solid State	646	3B	0.064	CW	N/A	1.4

☐ **Cryogen Use**

No cryogens are used.

☐ **Chemicals & Compressed Gasses**

No chemical or compressed gasses are used.

☒ **Electrical Hazards**

Alignment and operation of these laser systems requires no work on the power supplies. **No Users are authorized to work on the laser power systems.** Any maintenance or troubleshooting on the power systems 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]).*

The set up includes a PI Acton SpectraPro SP-2500i Imaging Spectrograph, an Olympus microscope, a custom-made microscope, and various optical components used to direct and condition the beam for Raman and fluorescence measurements as well as pressure calibration.

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.

Class-3A DPSS laser: The <3 mW, ANSI Hazard Class 3A, laser (532 nm) is used to excite ruby fluorescence for pressure calibration only. It is not interlocked for personnel protection. The measured power along the open beam path is <3 mW. The beam path is enclosed for this laser except for the sample area.

Class-3B DPSS Solid State Laser: This 150 mW ANSI Hazard Class 3B laser (532 nm) is used for Raman and photoluminescence measurements. Eyewear for this DPSS system (see Eyewear Requirements Table) will be worn during alignment and checking of this system. The beam path is enclosed for this laser except for the sample area.

Class-3B Compact Solid State Laser: This 64 mW ANSI Hazard Class 3B laser (646 nm) is used for Raman and photoluminescence measurements. Eyewear for this laser (see Eyewear Requirements Table) will be worn during alignment and checking of this system. The beam path is enclosed for this laser except for the sample area.

Class-4 Argon Ion laser: The 6 W, ANSI Hazard Class 4, system is for Raman and photoluminescence measurements. Although capable of 6 W of total output power, the system is typically operated with single wavelength at 0-500 mW during routine operation. There is a shutter in front of the laser head and interlocked through the laser power supply. The beam path is enclosed for this laser except for the sample area.

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

Where practical, the beam path is enclosed with opaque covers made of aluminum tubes. These covers are attached to the optical table and require a tool for removal. Only the Owner/Operator can open the enclosure for alignment/checking.

Beam Stop and Attenuator

The Argon-Ion laser is configured with a beam stop directly downstream of the laser aperture. This stop is incorporated to the personnel protection interlock. This same laser is also configured with a set of optical filters of varying density that are arranged on a wheel and can be used to control the power output of the beam downstream of the device. This filter wheel is located directly downstream of the beam stop. The other three solid-state lasers at U2A are configured with a beam stop in front of each laser's exit and share the attenuators with the Argon-ion laser.

The microscope used to position samples in the beam is equipped with a set of filters designed to protect personnel while looking into the scope. These filters have an optical density rating of 3 for light wavelengths between 600 and 1000 nanometers. These filters require a tool for removal and provide adequate protection for an observer's eyes at any laser wavelength or power that can be delivered to the microscope. **These filters are never to be removed from the microscope.**

Activation Warning System

The U2A hutch acts as the Laser Controlled Area for all four laser systems. The hutch is constructed of material that is opaque to the laser light wavelengths in use and there is an activation indicator that lights up when the Argon ion laser is energized.

Key Controls

All lasers have a key control on the power supply. The keys are kept under the control of the laser owner/operators. Access to these keys are controlled by the laser owner and only supplied to qualified laser 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.

Personnel Protection Interlocks

The personnel protection interlocks in service at U2A were designed, installed, and are maintained and tested by the NSLS Interlock Working Group. The system is configured to control the position of the beam stop of the Argon-Ion laser and to assure that the laser controlled area is secured before allowing the shutter to open. The solid-state laser's outputs are **NOT** included in the personnel 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 Photon Sciences ESH group.

Emission Delay

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

ADMINISTRATIVE CONTROLS

☒ Laser Controlled Area ☒ Signs ☒ Labels ☒ Operating Limits

Administrative Controls Description:

Laser Controlled Area

Class 3B and 4 lasers are required to be operated in Laser Controlled areas with appropriate warning signs and labels. The U2A hutch acts as the Laser Controlled Area for all laser systems. 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.

Signs and Labels

A warning sign provided by the BNL LSO is posted at the entrance to the Laser Controlled Area. The wording on that sign is as follows:

Danger
Laser Radiation
Avoid eye or skin exposure to direct or scattered radiation
Authorized personnel only

The manufacturer of each laser has affixed warning labels to each device that indicate the ANSI hazard class of each laser.

Operating Limits

Whenever possible alignment is to be conducted with beam power less than 5 milliWatts.

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.

See Appendix #3 for the SOP for the U2A laser systems.

PERSONAL PROTECTIVE EQUIPMENT

☐ Skin Protection ☑ Eye Wear

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.

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 Diameter (mm)
Argon ion	457.9 - 514.5	4	6.0	CW	N/A	2
Diode Pump Solid State (DPSS)	532	3A	0.02 (rated) 0.003 (measured)	CW	N/A	2
Diode Pump Solid State (DPSS)	532	3B	0.150	CW	N/A	0.32
Compact Solid State	646	3B	0.064	CW	N/A	1.4

EYEWEAR REQUIREMENTS					
Laser System Hazard	Wavelength (nm)	Calculated Intra-beam Optical Density	Diffuse Optical Density*	NHZ** (meters)	Appropriate Eye Wear***
Argon ion	457.9-514.5	3.8 (0.25 sec.)	1.7	1.4 m	Laser – Guard for Argon ion (yellow color)
Diode Pump Solid State (DPSS) (<5 mW)	532 (3A)	NA	NA	NA	No need
Diode Pump Solid State (DPSS)	532 (3B)	2.2 (0.25 sec.)	NA	< 20cm	Laser – Guard for Argon ion (yellow color)
Compact Solid State (64 mW)	646	1.8 (0.25 sec.)	NA	< 20cm	Laser-Gard LGS HN

EYEWEAR SPECIFICATIONS		
Laser System Eyewear Identification***	Wavelengths	Optical Density
Narrow Spectrum Laser - Guard **Argon – Ion Laser**	190 – 532	>9.0 @ 190 - 520 nm >4.5 @ 520 - 532 nm
Narrow Spectrum Laser - Guard **Ti:Sapphire Laser**	780 – 1070	>3.0 @ 780 - 845 nm >4.5 @ 850 -1070 nm
Laser – Guard HN	650	>2 @ 646 nm

*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.

General Alignment

Procedural Considerations

1. To reduce accidental reflections, watches, rings, dangling badges, necklaces, reflective jewelry are 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.
4. All equipment and materials needed are present prior to beginning the alignment
5. All unnecessary equipment, tools, combustible material (if fire is a possibility) have been removed to minimize the possibility of stray reflections and non-beam accidents.
6. Persons conducting the alignment have been authorized by the RI.
7. A NOTICE sign is posted at entrances when temporary laser control areas are setup or unusual conditions warrant additional hazard information be available to personnel wishing to enter the area.

Alignment Methods to be used for this laser

1. There shall be no intentional intrabeam viewing with the eye. (This statement must remain. Do not delete.)
2. Co-axial low power lasers should be used when practical for alignment of the primary beam.
3. Reduce the beam power through the use of ND filters, beam splitters and dumps, or reducing power at the power supply. Avoid the use of high-power settings during alignment as much as is practical.
4. Laser Protective Eyewear shall be worn at all times during the alignment, within the parameters and notes established on the accompanying laser table.

5. (this paragraph must be accepted or deleted in it's entirety) The LSO has authorized reduced optical density eyewear to allow the beam spot to be seen. Measures shall be taken and documented to ensure that no stray hazardous specular reflections are present before the lower OD eyewear is worn. A return to the Maximum OD eyewear as listed in the laser table will be made when the alignment is complete. The eyewear is labeled as alignment eyewear and is stored in a different location than the standard laser eyewear for this operation.
6. Skin protection should be worn on the face, hands and arms when aligning at UV wavelengths.
7. Beam Control- the beam is enclosed as much as practical, the shutter is closed as much as practical during course adjustments, optics/optics mounts are secured to the table as much as practical, beam stops are secured to the table or optics mounts.
8. Areas where the beam leaves the horizontal plane shall be labeled.
9. Any stray or unused beams are terminated.
10. Invisible beams are viewed with IR/UV cards, business cards or card stock, craft paper, viewers, 3x5 cards, thermal fax paper, Polaroid film or similar technique. Operators are aware that specular reflections off some of these devices is possible, and that they may smoke or burn.
11. Pulsed lasers are aligned by firing single pulses when practical.
12. No intra-beam viewing is allowed unless specifically evaluated and approved by the LSO/DLSO. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
13. Normal laser hazard controls shall be restored when the alignment is completed. This includes enclosures, covers, beam blocks/barriers have been replaced, and affected interlocks checked for proper operation.

TRAINING

LASER SAFETY TRAINING

Laser Operators must complete sufficient training to ensure 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 using the checklist in Appendix #4 that includes**

- Brief list of topics covered e.g.,
  - Review of SOPs;
  - Review of working procedures, and other program specific documentation.

System-specific training is documented on the Laser OJT Form (LS-TRN-CRF-0018) located at: http://www.nsls.bnl.gov/training/Courses/Lasers/LS-Laser-OJT-form.pdf, which requires:

- - SOP Number (and revision number, if applicable)
- - Trainee name and signature
- - Owner/Operator signature
- - Date

These forms are submitted to the Training Coordinator for entry into BTMS.

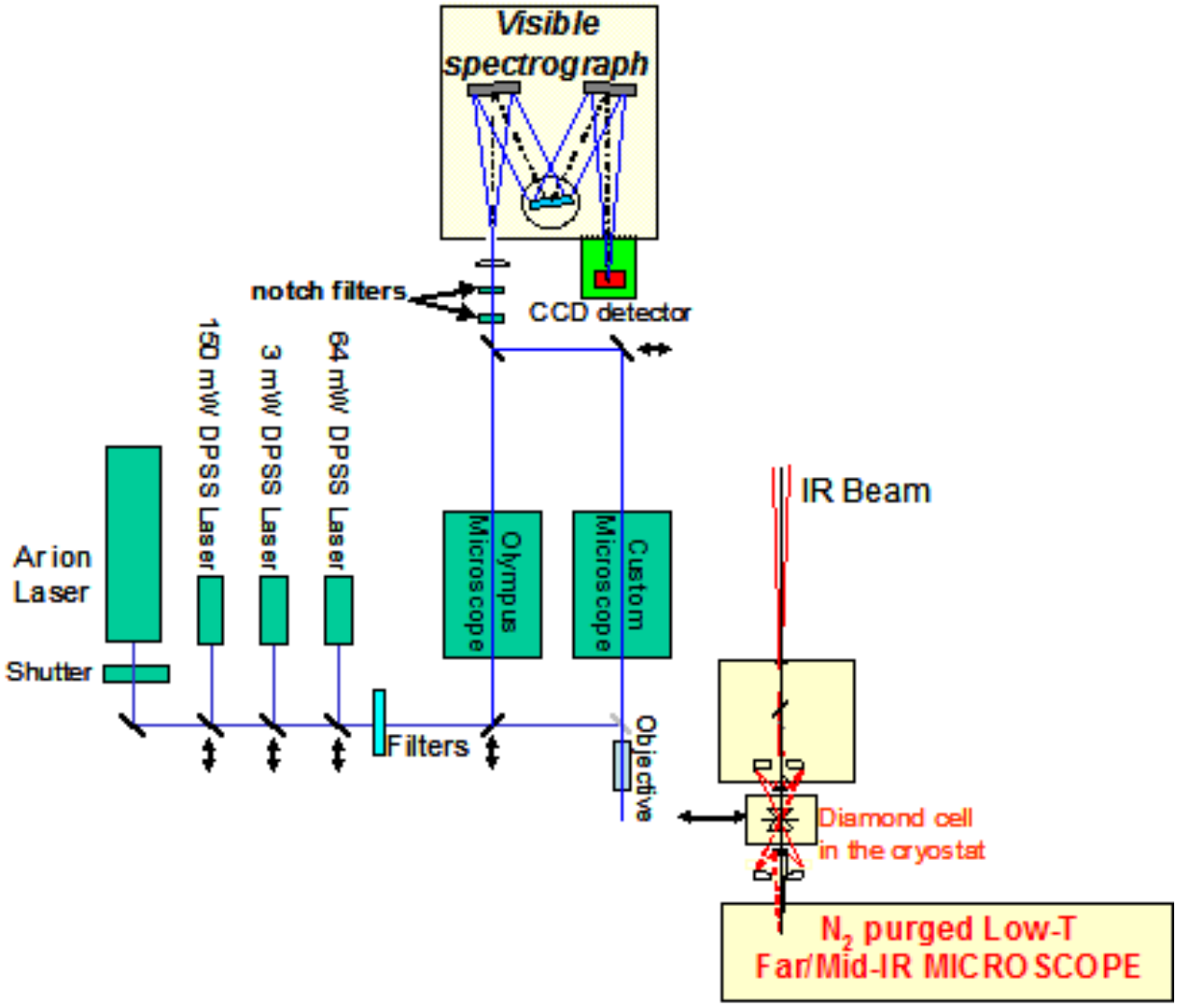
All laser safety training must be repeated every two years.

A U2A laser system specific training checklist is included here as Appendix #4. A binder is kept near the area for:

-- 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.

Appendix #1. Schematic diagram of laser system at U2A



Appendix #2
Personnel Protection Interlock Description

Operation of the U2A Laser Interlock System
Prepared by Scott Buda; 11/18/2005

This document describes the operation of the NSLS Standard Laser Interlock System in a typical installation that has a laser power supply with interlock input and a laser shutter. The laser shutter in most cases is a commercial shutter with out position read back. The room typically has a single door used to access the laser area to be protected and an lighted “Laser Interlocked” sign above the door inside and out. A control station inside and outside of the area allows the user to search the area and control the shutter.

1. Emergency Stops
   The system has emergency stops located on each control station located on the inside and outside of the laser interlocked area. Pressing the emergency stop will remove the factory interlock from the laser power supply, remove the shutter open command and dump the interlock search.
   This will require the authorized operator to reset the system with the reset key. The Emergency Stop can be reset by twisting the button. The area will need to be searched again to activate the interlock.

2. Area Search
   In order to operate the laser, the laser interlocked area must be searched for personnel and no person can be left in the area immediately after the search is performed. To reinforce the search s sequence of buttons must be pressed in order to complete the search.
   To begin the search enter the laser area and visually look for personnel in the area, if none are 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 complete the area is ready for laser light.

3. Interlock Off
   If the laser interlocked area is no longer needed to be interlocked to turn off the interlock system in an orderly manner, close the laser shutter and press the Interlock Off button. This will bring the interlock to the ground state. If a door is opened while the area is interlocked a warning will sound and the laser responsible person will have to reset the system with the reset key.

4. Shutter control

The shutter may be opened from either the inner or outer control station. Press the Open button to open the shutter and press the Close button to close the shutter. After pressing the open button two short beeps indicate that the shutter is going to be opened.

5. Pass Through

A person trained and authorized may enter the laser area with the proper PPE using the Pass Through function.

After the area is searched and the area is interlocked, to enter the laser 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 enter the laser area and close the main door. Once inside the laser area 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 20 second limit. If the door is open for more than 20 seconds the Pass Through function will reset and dump the interlock. To exit the area reverse the process completing it with pressing the outer Pass through button. When pressing the Pass Through buttons a light in the button confirms the 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 gives the laser operator a means of disabling the interlock system from operating. The key may be removed locking the system out.

Appendix #3
Standard Operating Procedure (SOP)
U2A Class 3B&4 Laser System

1. Argon laser maintenance

The maintenance procedures for the Argon ion laser are only to be performed by the manufacturer, Coherent Company. Other two class-3B lasers are maintained by the manufactures, Spectral Physics and CrystaLaser, respectively.

2. Alignment procedures for Argon laser, 150 mW DPSS green laser, and 64 mW compact red laser systems

These alignment procedures are only to be performed by the laser owner/Operator.

Attention: only the Laser System Owner/Operator is authorized to complete beam alignments.

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.
and:

An operator is aligning

OR

There is an open beam path > 15 cm.

a. Verify the presence of the color filter (red) using the incandescent light source before proceeding with the alignment.

b. Gross alignment: During gross alignment of the argon laser, neutral variable density filter (OD 0.04~2, 400~700nm) will be placed in front of the Argon laser. The power needed in this case is always smaller than 5 mW (considered as class 3A laser), which is identified by a laser power meter. The density filter will not be moved until the beam is fully aligned. The laser shutter is interlocked to the hutch door to eliminate hazardous reflections onto the experimental floor and to establish the laser-controlled area.

c. Spectrometer and signal alignment: Following the gross alignment described above, sample, spectrometer and signal parts need to be aligned to optimize the signal. The output power needed in this case is between 100 and 300 mW (power bellow 100 mW is too weak to align the signal path). The neutral variable density filter is removed. Again, optical paths around the sample place, especially near a walkway, are enclosed as much as possible to minimize exposure to low intensity stray reflections and scatter after the alignment. Further alignment at this power is performed utilizing the CCD camera.

3. Operation procedures for signal alignment.

Attention: all authorized personnel must follow the procedure as follows:

- Close the door to the Laser Controlled Area (U2A beamline hutch); satisfy the personnel protection interlocks.

- Never leave the system unattended during operation.
- Assure proper configuration of the optical path and LCA (checklist).
- **Check the laser orange/red filters are on the microscope position again.**
    - Turn on the white light microscope illuminator and see red light in the microscope eyepiece
- Never try to observe laser beam directly even with safety goggles.
- Turn Argon/green/red laser on.
- Very carefully proceed with the optical alignment coaxially for all mirrors and lens utilizing the CCD detector's signal level as an indication until the signal is optimized.
- The CCD detector should be cooling down about 30 minutes with L-N2 before using it.
- Using WinSpec/32 and WizSpec programs to do the signal/noise ratio measurement until the ratio is bigger than the desired one.

4. Operation procedures for sample measurements

- Close the door to the Laser Controlled Area (U2A beamline hutch); satisfy the personnel protection interlocks.
- Never leave the system unattended during operation.
- Never try to observe laser beam directly even with safety goggles.
- Assure proper configuration of the optical path and LCA (checklist).
- The CCD detector should be cooling down about 30 minutes with L-N2 before using it.
- Align DAC to focus sample on the microscope with an illuminator (#3 above).
- **Check the laser orange/red filters are on the microscope position again.**
- Turn laser on. Find the interested sample region with microscope.
- Do measurement with WizSpec/32 program.
- If you are not using laser system within 30 minutes just use beam stop to block laser beam and leave the laser on.
- When the measurement is done, turn the laser off, leave the cooling system on about ten minutes and then turn it off.

Appendix #4
Training Checklist for the U2A 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 Raman/fluorescence 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 U2A Laser System Owner is required for Level I operation of class-4 (Argon ion laser) and class-3B (green and red) DPSS lasers U2A.

- ☐ Read and understand the U2A Laser Systems Standard Operating Procedure (LS – ESH – 0026).
- ☐ Demonstrate understanding and operation of the laser personnel protection interlock (for Argon ion laser only).
- ☐ Demonstrate understanding and operation of laser shutter and power attenuation filters **(including the microscope attenuator filters)**.
- ☐ Identify appropriate eyewear and when use is required.
- ☐ Demonstrate understanding and completion of signal alignment procedure.
- ☐ Acknowledge that laser system operators are not permitted to work on laser power systems and are not authorized to complete beam alignment.
- ☐ Complete laser measurement 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.