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: Source of Photoexcitation for the pump-probe (time-resolved) experiment
Location: Inside the U6 and U13 beamline laser hutch, VUV experimental floor, Bldg. 725 (NSLS).

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:	G.L. Carr	*Signature:* *On file*	*Date:*
	J. Rameau (U13 portion)	*On file*	

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	*Signature*	*Date*
Chris Weilandics	*On file*	

ES&H Coordinator printed name	*Signature*	*Date*
Lori Stiegler	*On file*	

APPLICABLE LASER OPERATIONS
x General Operation x Alignment x Service/Repair ☐ Specific Operation x 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 *(Argon, CO2, etc)*	Wavelengths (nm)	ANSI Class	Maximum Power of Energy/Pulse	Pulse Length	Repetition Rate
1 Coherent Ti Sapphire	700 to 950	IV	20 nJ	2 picosecond	106 MHz
2 Coherent Nd:YVO_4	532	IV	CW, 10.5 Watts	CW	CW

☐ **Cryogen Use**

Describe type, quantity, and use

None

☐ **Chemicals & Compressed Gasses**

Describe type, quantity, and use.

Nitrogen purge gas from NSLS N2 purge system (boil-off). Basic solvents (mainly methanol, possibly acetone) used for cleaning optics. Dessicants used for protecting optics. Compressed gas cylinders are not used. Total quantity of solvents below 250ml (two small small dropper bottles) and stored in secondary containment vessels.

☐ **Electrical Hazards**

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

Standard 115V AC

☐ **Other Special Equipment**

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

Standard Diagnostic Equipment: oscilloscopes, photodetectors, power meters, PC-based synchronization system, electro-optic pulse pickers, IR converter/viewer.

Laser System Configuration 1: Describe the system controls *(keys, switch panels, computer controls),* beam path and optics *(provide a functional/block diagram for complicated beam paths)*.

PURPOSE: Configuration 1 is for delivering Ti:sapphire laser pulses from the U6 hutch, within a Kevlar™ reinforced optical fiber cable, to a light-tight enclosure at either U4IR or U12IR infrared beamlines. This is for photo-induced time-resolved infrared spectroscopy.

Turning the key switch on the power supply front panel starts the Nd:VO_4 laser (Coherent Verdi) producing 10.5W or less of CW light at 532nm. With the Verdi shutter open (nominal state), the Verdi light is directly coupled to the Ti:Sapphire (Mira) laser for optical pumping. The Mira produces 2W or less of CW or pulsed, near IR laser light that is delivered through the Mira's fast photodiode for pulse synchronization. The primary U6 safety shutter (interlocked) is located immediately downstream of this synchronization photodiode. From here, the near-IR laser light is available on the U6 optical table, passing through correcting optics and fast pockels cells for pulse selection. A second shutter (not part of the safety interlock system) and a second fast silicon photodiode (for monitoring the pulse picker performance) precedes the coupling of the Ti:sapphire laser pulses into a reinforced optical fiber cable for transporting the light to an enclosed sampled chamber at U4IR or U12IR beamline area. An optional frequency doubler (2^{nd} harmonic, λ = 350nm to 460nm, <200mW) is placed before the fiber coupler when visible/near-UR photoexcitation is required by the experiment. Note that the Configuration 2 optical path has a separate and additional interlocked shutter that is disabled (locked-out) whenver the U13 laser enclosure is not secured and interlocked for operations. A block diagram below illustrates the beam path.

See Appendix A for a description of the fiber feed into the U4IR or U12IR spectrometer cryostat endstation.

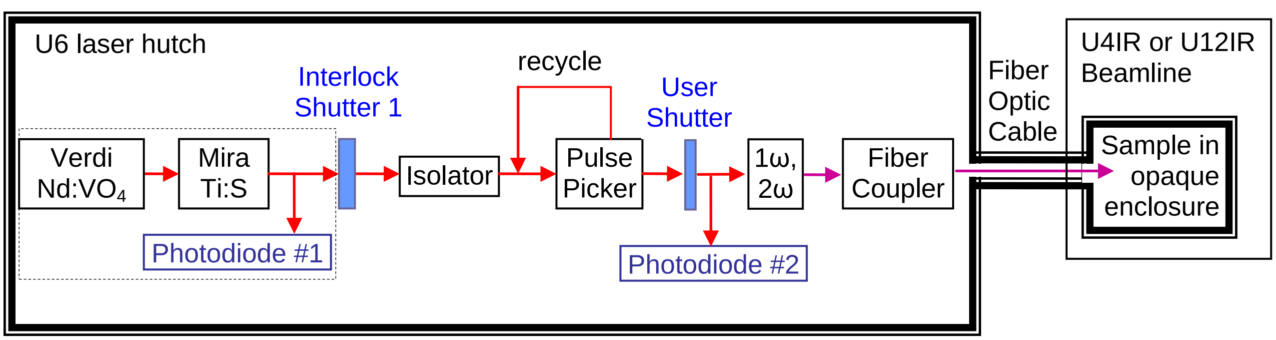

Figure 1: Schematic diagram of the U6 Ti:sapphire laser configuration for infrared time-resolved spectroscopy.

Laser System Configuration 2: Describe the system controls *(keys, switch panels, computer controls),* beam path and optics *(provide a functional/block diagram for complicated beam paths)*.

PURPOSE: Configuration 2 is for delivering Ti:sapphire laser pulses from the U6 laser hutch through a solid pipe to the U13 laser controlled hutch where harmonics are produced for use in photoemission spectroscopy at the U13 beamline endstation.

Turning the key switch on the power supply front panel starts the Nd:VO_4 laser (Coherent Verdi) producing 10.5W or less of CW light at 532nm. The Verdi light is directly coupled to the Ti:Sapphire (Mira) laser for optical pumping. The Mira produces 2W or less of CW or pulsed, near IR laser light that is delivered through the Mira's fast photodiode. The primary U6 safety shutter (interlocked) is located immediately downstream of this synchronization photodiode. From here, the Mira near-IR laser light is directed (using mirrors) through a second safety shutter and into the U6-to-U13 beam transport pipe. This second safety shutter is located at the entrance to the U6-to-U13 beam transport pipe and is interlocked with the U13 laser hutch enclosure such that the shutter can only be opened when the U13 laser enclosure is secured and interlocked for laser operations. The Mira's near-IR (λ = 800nm, 1.5eV fundamental) laser pulses are focused through two second harmonic generation (SHG) crystals to produce both the 2^{nd} (λ = 400nm, 3eV, up to 250mW) and 4^{th} (λ = 200nm, 6eV) harmonics. The near-IR fundamental is filtered out immediately after the 1^{st} SHG stage (part of the commercial Inrad harmonic generator). Both the 2^{nd} and 4^{th} harmonics are then fed inside a fully enclosed metal vacuum pipe from the U13 laser enclosure to the U13 photoemission spectrometer endstation. The safety goggles and glasses discussed below are adequate for the powers and wavelengths of the Mira's harmonics. A block diagram below illustrates the beam paths.

See Appendix sections A.2 and A.3 for a description of the laser configuration and use at U13.

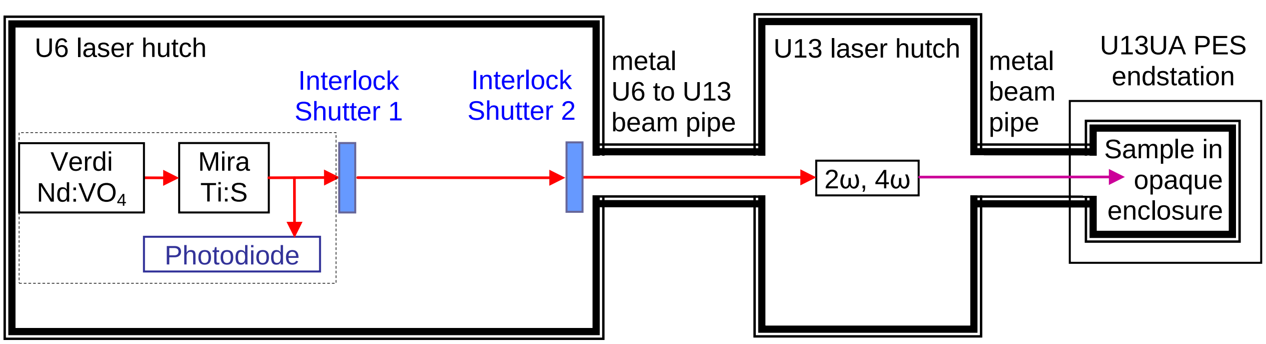

Figure 2: Schematic diagram of the U6 Ti:sapphire laser configuration for photoemission spectroscopy at beamline U13.

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 SBMS Subject Area, Electrical Safety, Section 6, 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. **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:

Beam Enclosure: Laser beam is contained within the Verdi V10 pump laser, the Verdi-to-Mira 900P beam transfer optic enclosure and the Mira 900P enclosure. These are not interlocked, and must be in proper position for containment. The Mira 900P lids must also be installed. See Configuration Control.

Beam Stop or Attenuator: The Verdi V10 has an internal shutter, controlled from the Verdi power and control unit. When this shutter is closed, all laser light is contained within the laser head and no emission reaches the Mira 900P nor can it exit anywhere onto the U6 laser table.
The Mira 900P has a shutter immediately downstream of the Mira Fast Photodiode at the beam exit of the Mira 900P. This shutter serves as the primary shutter for the hutch interlock system. When this shutter is closed, beam from the Verdi can still pass from the Verdi to the Mira 900P. This shutter also has a reach-back capability – in the event that the shutter does not properly close when commanded to close, the interlock system will break the Verdi's internal interlock causing its internal shutter to close.
A final shutter is located downstream of the pulse pickers and upstream of the fiber couplers. This shutter is used only for controlling light entering the fiber coupler.

Activation Warning System: In order to engage the laser hutch interlock, the operator must initiate a search of the laser hutch enclosure. When this search is completed, the operator presses the "Complete

Search” button on the exterior interlock control panel. A red “INTERLOCKED” light above the laser hutch entrance illuminates and a warning siren sounds inside the laser hutch for a period of time. This same siren sounds for a few seconds each time the interlocked Mira laser shutter is opened.

Other Interlocks: The U6 hutch allows properly trained and protected personnel to work with the laser system optics. All hazards are contained within the hutch. The laser system is turned on by a key which is accessible only to approved personnel.

An interlock system on the hutch doorway entrance is interfaced to a shutter directly at the exit aperture of the laser. Entry by unauthorized personnel trips the interlock causing the beam to be contained inside the laser’s own enclosure.

Containment of the laser radiation is achieved by the following systems:

Laser system configuration 1
1A) the housing for the Verdi V10 pump and Mira 900P Ti:sapphire laser oscillator.
1B) the U6 laser hutch enclosure and the door/shutter interlock system
1C) the reinforced optical fiber cable from the U6 laser enclosure to the infrared beamline
1D) the endstation enclosure at the IR beamline

The optical fiber cables run inside the standard cable trays above the VUV ring itself, and are therefore not normally accessible to unauthorized personnel. The Kevlar reinforcing fibers provide protection against inadvertent breakage. The cables are labeled at ~ 4 meter intervals to indicate that they may be carrying near-IR laser or visible/near-UV light.

The cables end at the beamline with an SMA type connector. A rigid screw-type union connector attaches the cable to another cable which ends inside an enclosed sample/experiment chamber, or an optical photodiode detector enclosure.

Laser system configuration 2
2A) the housing for the Verdi V10 pump and Mira 900P Ti:sapphire laser oscillator.
2B) the U6 laser hutch enclosure and the door/shutter interlock system
2C) the U6-to-U13 transport pipe (metal, under vacuum).
2D) the U13 laser enclosure and interlock system
2E) the U13 enclosue to endstation metal pipe (under vacuum)
2F) the U13 endstation enclosure

The U6 hutch allows properly trained and protected personnel to work with the laser system optics. All hazards are contained within the hutch. The laser system is turned on by a key which is accessible only to approved personnel.

The U13 laser hutch enclosure allows properly trained and protected personnel to work with the laser system optics. All hazards are contained within the hutch.

For both enclosures, an interlock system on the hutch/enclosure doorway entrance is interfaced to a shutter. For U6, the shutter is situated directly at the exit aperture of the laser so that the beam is contained inside when the shutter is closed. Entry by unauthorized personnel at U6 trips the interlock causing the shutter to close. For U13, the shutter is situated inside the U6 laser hutch/enclosure at the entrance to the U6-to-U13 beam transport pipe. Entry by unauthorized personnel at U13 trips the interlock causing the shutter to close, preventing any laser light from entering the transport pipe from U6 to U13.

Interlock Systems: a copy of the design and the testing checklist is included.

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:

The controlled laser hutch enclosures are posted with standard signs describing the systems within. A safety checklist indicates the required status of the optical system prior to energizing the laser system(s). The hutch enclosures have an NSLS standard-type sign that is illuminated whenever the interlock is active. To gain entry without tripping the interlock requires that a person push a special bypass button and move through door in a short time period (~ 30 seconds) before the door-sensing interlock system becomes active again.

A fully authorized laser operator or approved service engineer must be present inside the U6 laser hutch enclosure during any alignment or adjustments where the Verdi-to-Mira transport covers and tubes are removed and/or the Mira 900P covers are removed and the Verdi V10 is in an operational state.

STANDARD OPERATING PROCEDURES

The standard operating procedures are contained within the appendices to this document.

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.

Safety Configuration Checklist
U6 Laser System

This checklist must be completed BEFORE engaging the U6 hutch enclosure interlock system and BEFORE powering the Coherent Verdi pump laser.

1. ☐ Confirm that the entrance door for the U6 hutch enclosure has all the proper Laser Hazard postings in place.
2. ☐ The Verdi-to-Mira beam tubes are properly installed.
3. ☐ The Mira exit shutter is in the CLOSED position.
4. ☐ The Verdi and Mira covers are in-place so that all laser emission will be contained.
5. ☐ The mirror for switching beam out to the U13 shutter is in the proper position.
6. ☐ Any other changes to the optical system on the laser table are noted.
7. ☐ All the required laser safety glasses are in good condition and ready for use.

This checklist is duplicated in Appendix E along with a separate configuration control checklist for the U13 laser hutch enclosure.

PERSONAL PROTECTIVE EQUIPMENT

☒ Eye Wear ☐ Skin Protection (not required)

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.

EYE WEAR REQUIREMENTS

Laser System Hazard	Wavelengths (nm)	Intra-beam Optical Density	Diffuse Optical Density*	NHZ**	Appropriate Eyewear***
Coherent Ti:Sapphire	700-950	(700) 3.3(0.25s) (950) 3.2(10s)	3.77(600s. diff)	15.3 m	Glendale GPT 2175, GPT 2226
Harm. Generator 205-410 nm	205 (UV) 410 (vis.)	5(10s) 2.3(0.25s)	1.5(600s) 1(600s)	1.2m 0.6m	Glendale GPT 2175, GPT 2226

Glendale GPT 2175 (Brown)			For use with Nd:YVO_4 &Ti:sapphire (fundamental and harmonics)
Glendale GPT 2226 (Green)			For use with Ti:sapphire (fundamental and harmonics) but NOT Nd:YVO_4 (green)
Wavelength [nm]	OD	OD	
190-420	9+		Ti:Sapphire / Mira Harmonics (from Coherent/Inrad harmonic generator)
532		7+	Nd:YVO4 / Verdi pump laser
190-520		9+	
710-750	3+	3+	Ti:Sapphire / Mira fundamental
750-860	5+	5+	Ti:Sapphire / Mira fundamental
860-1080	7+	7+	Ti:Sapphire / Mira fundamental
5000-11000	7+	7+	

Make sure the eye protection you use is adequate for the sources of light!!!

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.
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.

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.

SKIN PROTECTION:

Operators will minimize risk of skin exposure by wearing long sleeves and other skin protection during alignment procedures or when in the vicinity of the UV beams.

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).

Qualified Laser Operators must also complete system-specific orientation with the system owner/operator. **System-specific training topics are documented in Appendix D. Laser training is documented on the Laser OJT Form found at: http://www.nsls.bnl.gov/training/Courses/Lasers/**

All laser safety training must be repeated every two years.

MEDICAL SURVEILLANCE

Operators of ANSI Class IIIb and IV 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	631 751-2020	631 369-0777

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).

APPENDICES: The following appendix sections cover details for the two categories of laser measurements performed using the U6 Ti:sapphire laser system.

Appendix A contains an overview and description of both the U4IR/U12IR time-resolved IR spectroscopy measurement and the U13 photoemission measurement.

Appendix B describes alignment procedures, protocols and guidelines.

Appendix C describes details of the hutch enclosure personnel protection interlock systems.

Appendix D has the training checklists.

Appendix E has the Safety & Configuration Checklists.

APPENDIX A: Overview and Description of the Laser-Based Measurements

A.1 Time-Resolved, Pump-Probe Infrared Spectroscopy at U4IR and U12IR Infrared Beamlines

A.1.1 Laser-Synchrotron (Pump-Probe) Experiment Description

The primary purpose for the laser system is for performing time-resolved spectroscopy in the infrared spectral range. The laser produces short pulses of light which are used to illuminate and therefore photo-excite a sample specimen. These excitations can appear as changes in the sample's infrared properties. Immediately after the laser pulse, the excitations in the sample begin to relax, in some cases over time scales from 100 ps to 100 ns. The measurement goal is to obtain infrared spectra (using the synchrotron source and beamline spectrometer) during the various phases of the relaxation process.

To obtain spectra on such short time scales, the pulse structure of light from the VUV ring is exploited. The laser system produces pulses that are synchronized to VUV infrared pulses, but with a controlled time-delay between the two. Thus, the VUV pulses produce a momentary "snapshot" of the sample properties at an instant of time determined by the relative delay. The entire process repeats at a high repetition rate (10's of MHz) in a manner very similar to using a synchronized strobe light to "freeze" a particular moment of a repetitive process, allowing the slowly responding human eye to view it. An adjustable time-delay between the laser (pump) and VUV infrared (probe) pulses allows one to extract spectra at various times during the relaxation process.

To perform an actual experiment, the sample is placed in the standard compartment of an IR beamline spectrometer or inside a separate sample chamber (typically a low temperature cryostat). Pulses of VUV/IR ring infrared light are naturally incident on the sample using the beamline's standard optical systems. In order to photoexcite the sample, pulses of laser light must be brought to the same location. This is achieved using optical fiber cable, with the fiber ending inside the sample chamber and with optics to steer and control the spotsize of the laser illumination onto the sample specimen (sees Figure 1 on next page). Any residual laser light is prevented from reaching the detector using a blocking filter just upstream of the detector (not shown).

The relative arrival times of the VUV IR pulses and the laser pulses at the sample location must be measured in order to accurately set the pump-to-probe delay time. For this, a known sample of GaAs is placed at the focus of both the synchrotron IR (probe) and the laser (pump) and the relative delay adjusted until a maximum change in transmission is observed on the spectrometer's detector.

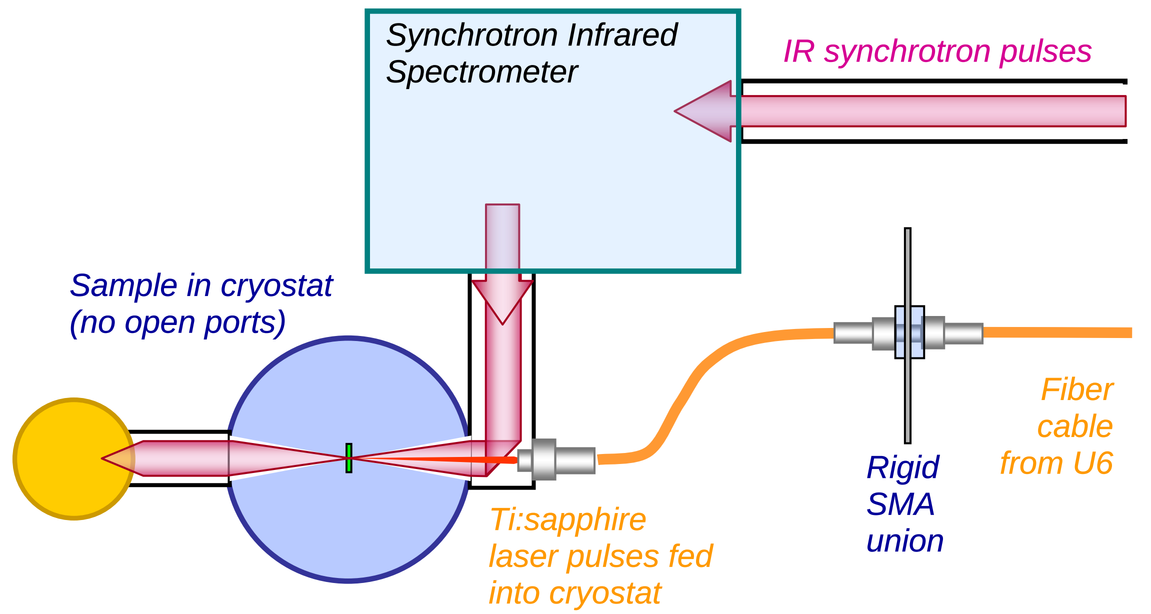

Figure 1: Schematic of typical time-resolved spectroscopy experiment at U4IR or U12IR.

For many measurements, the laser power onto the sample must also be known. The laser power available from the fiber at the beamline can be measured using a power meter having an SMA fiber receptacle directly attached. A Thorlabs power meter is used for this purpose. See figure 2.

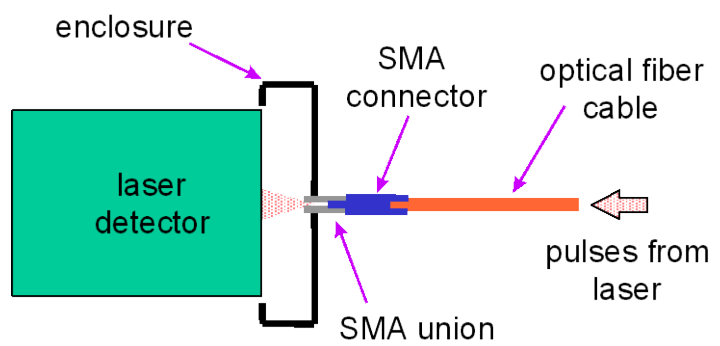

Figure 2. Measuring the laser power from the optical fiber.

Alignment of the optical fiber inside the sample chamber or cryostat, especially to place the end of the fiber at the proper distance from the sample and adjust the spotsize, will be done with the aid of a low power diode laser (~1 mW), coupled into the same fiber cable (see Figure 3). When connected, the visible spot on the sample can be safely viewed or imaged using a camera system (e.g., for high-field magnet cryostats where access is further restricted).

Whenever a fiber connector or detector is to be moved to another position for testing or measurements, the laser is turned off using a shutter having a signal feedback to ensure that it has properly closed. The shutter is not re-opened until the integrity of the beam containment has been confirmed.

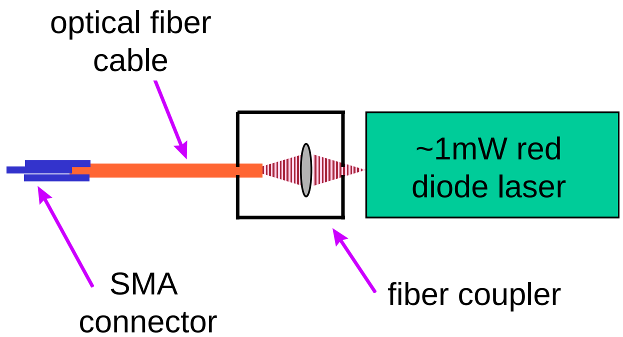

Figure 3. Low power visible light source (0.95 mW laser diode @ 670nm) coupled to optical fiber cable with SMA connector. This source of light can be fed into the cryostat or sample vacuum compartment to check alignment of the light beam onto the sample. This avoids the need for performing alignment with the Ti:S laser light itself.

Some sample chamber geometries are incompatible with any convenient direct viewing of the sample.

A.1.2 System details

A.1.2.1 Mode-locked, solid state Ti:S laser

The Ti:sapphire laser is a commercial “Mira” unit from Coherent Laser Group. It produces approximately 2 ps duration pulses of near infrared light at a repetition rate of 106MHz. The maximum power output (average) is approximately 2W. The energy per pulse is 20 nJ.The spectral range is tunable from 700nm to approximately 950nm. Though not presently installed in the U6 laser hutch enclosure, we plan to include a non-linear optical crystal for frequency doubling to produce visible and near-UV light in the 360nm to 450nm spectral range. The available power is not known, but we anticipate 200mW CW or less.

A.1.2.2 Pump laser

The Ti:sapphire laser is optically pumped with a frequency doubled $Nd:VO_4$ laser (532nm), producing up to 10.5 watts CW. The pump laser is also a commercial product from Coherent Laser group. The pump laser is directly coupled to the Ti:sapphire laser. Access to the pump laser light is rarely needed.

A.1.2.3 Pulse selection

A pulse selector (“pulse picker”) is used to match the various bunch patterns of the VUV ring. The system is a commercial package from ConOptics. Pulses are “down selected” to achieve 53MHz (for standard multi-bunch operation of the ring), 17.6 MHz (for symmetric 3-bunch operation) and 5.9 MHz (for single bunch operation). Rejected pulses are recovered, delayed, and re-introduced into the train of pulses from the laser.

A.1.2.4 Location

The laser is located inside the laser hutch enclosure at beamline U6 on the VUV floor. This hutch enclosure also contains the pulse selectors, diagnostic detectors, and fiber coupler. Windows on the hutch have been covered with solid aluminum sheet. Optical fiber cable is used to distribute the laser light pulses to a particular beamline on the VUV floor. Presently, this is limited to the U4IR D&I beamline, but we plan to move the programs down to U12IRto the sample cryostats IR beamlines managed and operated by L. Carr (the primary laser operator).

A.1.2.5 Light distribution

The laser light pulses are coupled into optical fiber cable and transported to a particular beamline endstation. The cable consists of a glass fiber contained within an acrylic buffer, Kevlar reinforcing fibers, and an opaque outer jacket. The fiber is large core, multi-mode type with a numerical aperture of 0.275. Therefore, light exiting the fiber expands into a cone with a ~30 degree vertex angle. SMA type 905 optical fiber connectors are affixed to the end of the fiber cable. Cables can then be securely connected with a screw-type union. Laser light is coupled into the fiber optic cable using a standard fiber coupler, located on the laser table inside the U6 laser hutch enclosure.

A.1.2.6 Experiment endstations

The optical fiber cable terminates in two types of endstations at the beamline. One is a diagnostic station, consisting of a fiber connector attached to a photodetector inside an opaque container. This is used for measuring delivered power and characterizing the pulses.
The other type of endstation is the specimen location in an infrared spectrometer set-up. This too will use an SMA fiber cable connector, with optical fiber leading directly to the specimen inside an enclosed, opaque, sample compartment. For measuring pulse timing, an enclosed detector with an SMA connectored input will be used.

A.1.3 Hazardous Beam Control and Procedures

Control of the laser radiation is accomplished by three systems: 1) the U6 hutch which houses the laser and accessory optics, 2) the optical fiber cable and 3) the endstation enclosure.
The U6 hutch allows properly trained and protected personnel to work with the laser system optics. All hazards are contained within the hutch. Protective goggles for both Ti:sapphire and Nd:YVO_4 wavelengths are located inside the U6 hutch. An interlock system on the hutch doorway entrance is interfaced to a shutter directly at the exit aperture of the laser. Entry by unauthorized personnel trips the interlock causing the beam to be contained inside the laser's own enclosure. The fiber cable runs along the cable trays above the VUV ring itself, and is therefore not normally accessible to unauthorized personnel. The Kevlar reinforcing fibers provide protection against inadvertent breakage. The cables end at the beamline with an SMA type connector. A rigid screw-type union connector attaches the cable to another cable which ends inside an enclosed sample/experiment chamber, or a fast optical detector enclosure.

A.1.3.1 general

All procedures will be conducted in a manner that maintains complete control of hazardous laser emissions.

A.1.3.2 training

Only specially trained personnel will be authorized to operate the laser system. These personnel must complete the NSLS laser safety training course and laser eye exam (see C. Weilandics), and laser-specific training (see L. Carr).

A.1.3.3 glasses and goggles

All potentially hazardous laser tasks will be conducted within the enclosed U6 beamline hutch enclosure. Protective glasses (Ti:sapphire only) or goggles (both Ti:sapphire and Nd:YVO_4) are to be used during such tasks (any time there is beam accessible outside of the shuttered Mira and Verdi containment).

A.1.3.4 postings

The doorway entrance to the U6 hutch will carry standard postings for both the pulsed Ti:sapphire laser, and the particular pump laser (presently a 10.5W Nd:YVO_4 solid state laser). A sign with the message “INTERLOCKED” will illuminate to indicate that the door system interlock is functioning.

A.2: Procedures for Operation of Ti:sapphire laser system For Photoemission Experiments at Beamline U13

Prepared by J.D. Rameau – Condensed Matter Physics and Materials Science Department

A.2.1 System description

A.2.1.1 Overview

The titanium-doped sapphire (Ti:Sapphire or Ti:S) solid state laser produces short duration pulses of light that can be synchronized with the light pulses produced by the VUV ring. The Ti:sapphire laser is optically pumped with a 10W CW frequency doubled Nd:YVO4 solid state laser system. The Ti:S laser's purpose is to either photoexcite materials which are then investigated using VUV light from the VUV storage ring -- two-photon photoemission -- or to perform high resolution single-photon photoemission after undergoing multiple harmonic generation processes.

- *Spectral range: Near IR (700nm to 950nm wavelengths).*
- *Average Near IR power: 2W.*
- *Harmonic Generator for 2nd and 3rd Harmonic (Inrad) of Ti:Sapphire fundamental*
- *Average 2nd Harmonic Power: < 250 mW.*
- *Average 3rd Harmonic Power: < 10 mW*
- *Average 4th Harmonic Power: < 2 mW*
- *Pulse repetition frequency: 106 MHz, 53 MHz*
- *Pulse duration: ~2 ps*
- *Peak energy per pulse: 20 nJ*
- *Laser location: Inside U6 beamline hutch on VUV floor.*
- *Distribution to beamline/experiment: Reinforced fiber optic cable and steel beam pipe*

In the single-photon Laser ARPES experiment, tightly focused DUV laser radiation is used to directly excite electrons from the surface of a sample for analysis of angular and energy distribution information in an SES-2002 photoelectron spectrometer. This is essentially the same experiment as is currently performed at the U13 end station but utilizing laser instead of synchrotron radiation- see SAF #3569 and its successors for details. In the two-photon experiment, fundamental Ti:S light is launched into a fiber in the U13A hutch and then injected into the laser beamline as outlined in the relevant 2ppe SOP.

A.2.2. Operations

A.2.2.1 Laser Operations at the U13A Hutch Laser Enclosure

The "A" side of the U13 hutch at the VUV ring has been converted into an interlocked enclosure inside of which trained personnel may utilize the Class 4 laser radiation supplied via beam pipe from the Ti:S laser located inside the U6 hutch. The enclosure of U13A is accomplished with a fixed laser safety curtain and another curtain, interlocked with a proximity switch, that can be zipped open and closed to permit entry to the enclosure by authorized personnel. When the curtain is closed, the interlock can be armed, illuminating signs inside and outside the hutch to indicate that the beam might be on (in U6) and that the shutter can be opened. Opening the shutter will cause another sign outside the hutch to be illuminated, indicating a laser radiation hazard. Timed pass through switches inside and outside the hutch will allow entry to authorized personnel without breaking the interlock. Breaking the interlock, e.g. by opening the curtain without use of the pass through switch, will cause the shutter to the beam pipe in U6 to close. The overall layout of the system if shown in Figure 1.

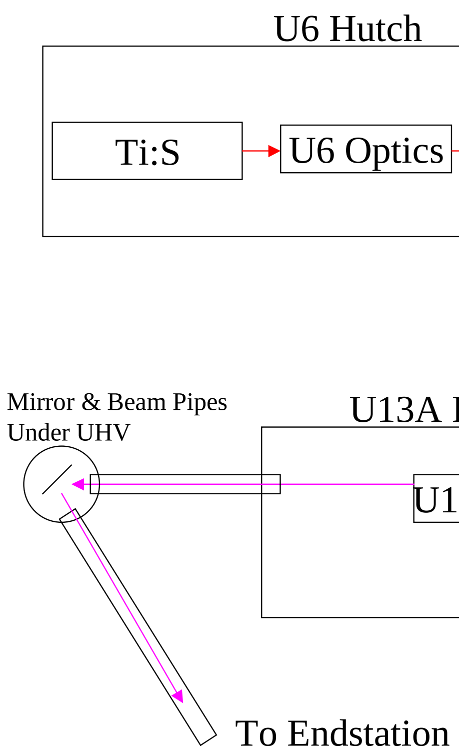

Figure 1. In a single photon laser ARPES experiment, light from the U13A laser enclosure travels through a single steel pipe to an optical stand where it undergoes a reflection and filtering out of visible light. It then travels through several refractive optics and is finally focused onto a sample mounted on the end of a liquid helium cryostat. During two-photon experiments the mirror will be retracted and the fiber optic port utilized for the delivery of visible and near IR light through the same optics set.

During an experiment, 2 ps pulses of 820 nm radiation are produced by the Ti:Sapphire laser at U6 running at 105 MHz (or less) repetition rate. This light is sent via beam pipe to the U13 laser hutch. At U13 the light is frequency doubled through Type 1 SHG in an LBO crystal to 410 nm in the Coherent/Inrad Harmonic Generator. The IR light is removed by a dichroic mirror in this device and then contained in a beam dump. The 410 nm light is then doubled through another Type 1 SHG process in a specially cut BBO crystal. After this fourth harmonic generation stage the blue/DUV beam is sent either to a spectrometer/beam profiler for diagnostic purposes or launched through a window into another evacuated beam pipe leading to the U13 endstation. Alternatively, near IR, visible (2nd harmonic) or UV (3rd harmonic) light may be launched directly into a fiber optic cable that leads to the U13B laser beamline. This apparatus inside the U13 laser hutch is diagrammed in Figure 2. The laser beamline and laser operations at the U13B endstation itself are described below.

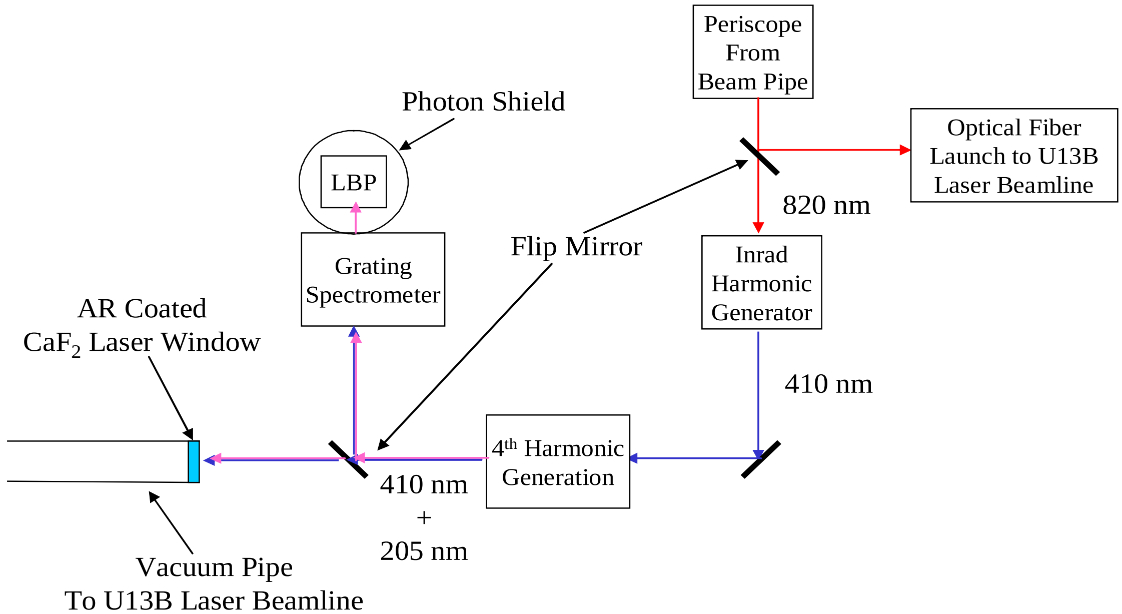

Figure 2. Laser light entering the U13A laser hutch undergoes harmonic generation before launching into the U13B laser beamline. Provision is made for spectroscopic and spatial diagnostics of the fourth harmonic beam (LBP = Laser Beam Profiler) and for launching the fundamental beam into a fiber optic for pump-probe experiments detailed below.

A.2.2.2 Operations at the U13B Laser Beamline and Endstation

Laser ARPES can be performed regardless of the state of operation of the VUV ring of the NSLS, e.g. during shutdowns and maintenance. In any event, all shutters to the U13B beamline will remain closed during single photon laser ARPES experiments. To perform an experiment, DUV light is produced collinearly with blue (visible) light as described above in section 1.2 and launched into the laser beamline through a window. The light first travels through a light-tight steel pipe to an optical stand on the opposite side of the U13B beamline from the laser enclosure. The beam then strikes an ArF mirror that allows ~99% of the blue light to pass through to be absorbed in a beam dump behind the mirror. The DUV light and less than 1 mW of blue light, used for alignment purposes, are reflected into a section of beamline that runs directly into the experimental chamber. The last optic in the beamline is a convex lens that is held inside the experimental chamber ~100 mm from the sample. This lens is in a tube whose position can be adjusted to change the focus on the sample. The light is focused through a 1 cm diameter clearance in a series of copper plates held in front of this lens. This arrangement is diagrammed in more detail in Figure 2.

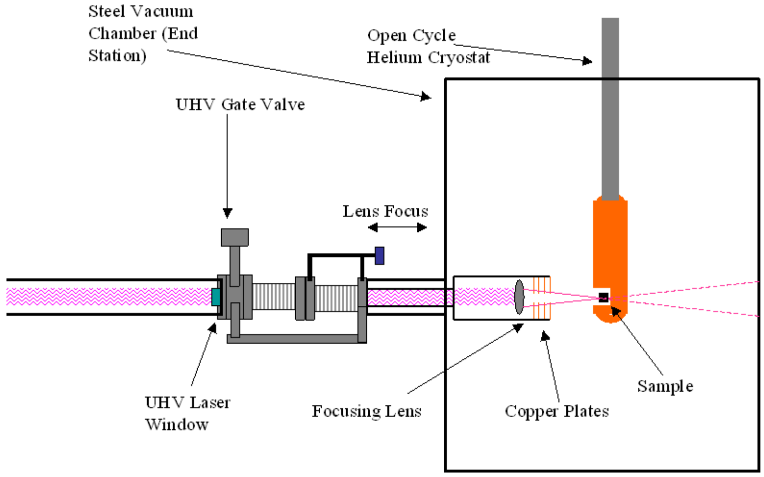

Figure 2. Light enters the focusing assembly from the laser beamline and is focused on the sample, which is glued to the cold finger of a liquid helium cryostat. The lens has a ~100 mm focal length. The laser beam can only pass through the lens if it is to enter the chamber and in the event the sample/cryostat is moved out of the way, or there is a stray reflection off it, the beam will automatically diverge dramatically and scatter off the inner walls of the chamber.

A.2.2.3 Beam Alignment and Confinement

Alignment will be facilitated by observing the blue (visible) beam collinear with the DUV beam through a CCD camera mounted to 2 ¾" viewports on the chamber and beamline. All other viewports will be blocked so that the beam is entirely contained within the system at all times.

The Ti:S beam emanating from the U6 hutch will be aligned through the U6 to U13 beam pipe by use of the same camera, feeding the image back to the operator in U6.

A.2.3. Procedures

A.2.3.1 Operations at U6 and U13A

All operations inside the U6 hutch will be carried out in accordance with the existing documentation for that laser system and laser controlled are. All operations at U13 will be carried out with the same attention to control of laser radiation hazards e.g. regarding safety goggles, flammables, etc.

A.2.3.2 training

Only specially trained personnel will be authorized to operate the laser system in either hutch. These personnel must complete the NSLS laser safety training course and laser eye exam (see C. Weilandics), and laser-specific training (see L. Carr or J.D. Rameau). Operators of the laser and related equipment in the U13 laser hutch must also be fully authorized as users of the laser system in the U6 hutch.

Personnel training and eye examination status will be documented in the BNL BTMS system through the NSLS Training Coordinator.

All personnel working with the laser system will complete the BNL web based training; TQ-Laser, will complete system specific training outlined in the training checklist below (Appendix D), and will complete the baseline eye exam.

A.2.3.3 glasses and goggles

All potentially hazardous laser tasks will be conducted within the enclosed U6 or U13 beamline hutches. Protective glasses (Ti:sapphire only) or goggles (both Ti:sapphire and Nd:YVO_4) are to be used during such tasks. The goggles to be used and their respective specifications are delineated in the SOP for operations at U6 and are adopted here. **Protective eyewear must be worn whenever personnel work in proximity to any open path ANSI hazard class 3b or 4 beam.**

EYE WEAR REQUIREMENTS					
Laser System Hazard	Wavelengths (nm)	Intra-beam Optical Density	Diffuse Optical Density*	NHZ**	Appropriate Eyewear***
Coherent Ti:Sapphire	700-950	(700) 3.3(0.25s) (950) 3.2(10s)	3.77(600s. diff)	15.3 m	Glendale GPT 2175, GPT 2226
Harm. Generator 205-410 nm	205 (UV) 410 (vis.)	5(10s) 2.3(0.25s)	1.5(600s) 1(600s)	1.2m 0.6m	Glendale GPT 2175, GPT 2226

* 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.

A.2.3.4 protective clothing

When the near IR Ti:sapphire laser beam is sent to the harmonic generator to produce blue and UV light, the operator will additionally wear long sleeved clothing to reduce the risk of skin exposure when performing any UV beam alignment.

A.2.3.5 postings

All possible entrances to the U13 laser hutch will be covered in appropriate laser warning signs provided by the BNL LSO. The pipe from U6 to U13 will be labeled and the flange clamps covered in a “seal” to prevent inadvertent exposure to laser radiation. Before rearming the beam pipe e.g. after a maintenance period the seals will be checked for integrity. Removal of any seals, clamps, etc. will require notification of the Op Co or control room.

A.2.3.6 radiation controls

The location of the U13 laser hutch next to the injector to the VUV rind and in the vicinity of the U13 front end will necessitate that the hutch be evacuated during injection and scheduled beam dumps.

A.2.3.6 alignment

All laser alignment will take place with goggles on and with the aid of an IR converter as necessary. Alignment of beam inside and on the way to the U13 end station will be carried out using a remotely viewed CCD camera so that even during alignment all laser radiation will be contained within steel vacuum vessels. Similarly, the CCD camera will be used to align the laser through the U6 to U13 pipe. We adopt all relevant recommendations in the standard alignment guide.

A.2.3.7 interlocks

Interlocks were constructed and will be maintained by the NSLS interlocks working group. An interlocks checklist will be maintained regarding biannual maintenance inspections and posted outside of U13.

A.3: Procedures for Operation of U6 Ti:Sapphire Laser System with Fiber-Coupled Pulse Transport to U13

J.D. Rameau – Condensed Matter Physics and Materials Science Department
NOTE: This procedure has been mostly supplanted by APPENDIX B, operation and procedures using a direct beam pipe and free-space transport from U6-to-U13.

A.3.1. System description

A.3.1.1 Laser Overview

The titanium-doped sapphire (Ti:Sapphire or Ti:S) solid state laser inside the U6 hutch produces short duration pulses of light in synchronization with the light pulses produced by the VUV ring. The Ti:sapphire laser is optically pumped with a 10W CW frequency doubled Nd:YVO4 solid state laser system. The Ti:S laser's purpose is to photoexcite materials which are then investigated using VUV light from the VUV storage ring. The object is to perform high resolution two photon ARPES (ar2ppe).

- *Spectral range: Near IR (700nm to 950nm wavelengths).*
- *Average Near IR power: 2W.*
- *Pulse repetition frequency: ≤ 53 MHz*
- *Pulse duration: ~2 ps*
- *Peak energy per pulse: 20 nJ*
- *Pump laser: <11W CW Nd:YVO_4 laser (532nm).*
- *Laser location: Inside U6 beamline hutch on VUV floor.*
- *Distribution to beamline/experiment: Reinforced fiber optic cable*

In the two-photon ARPES experiment Ti:S light is coupled into a Kevlar reinforced fiber optic cable that ultimately distributes the light to the U13UB high resolution ARPES end station. The laser light is focused onto samples – usually correlated electron materials – and excites carriers into the unoccupied state not normally accessible to an ARPES experiment. These carriers are then photoexcited by VUV pulses from the synchrotron. The resulting energy and angular distribution of the photoexcited electrons is measured by the SES-2002 photoelectron spectrometer.

A.3.1.2 Ti:S Laser in the U6 Hutch

The Ti:S laser, it's operation and the launching of its light into the fiber optic distribution system is exactly the same as for the laser based experiments at U4IR and U12IR and is covered under that document.

A.3.1.3 Distribution of Laser Light to U13UB

The fiber that carries light from the laser hutch at U6 to the U12IR end station terminates at a panel mounted SMA union. For ar2ppe experiments, a second multimode fiber can be plugged into that SMA union and run to the U13UB end station. That fiber can be safely terminated either 1) in a light tight, fiber-coupled power meter (Figure 1)

2) to a light tight, fiber coupled Silicon fast photodiode used for establishing the relative timing of laser and synchrotron pulses (Figure 1) or

3) to a small patch cable, by FC/PC union, that itself terminates inside the steel UHV vacuum chamber at the U13UB end station (Figure 2).

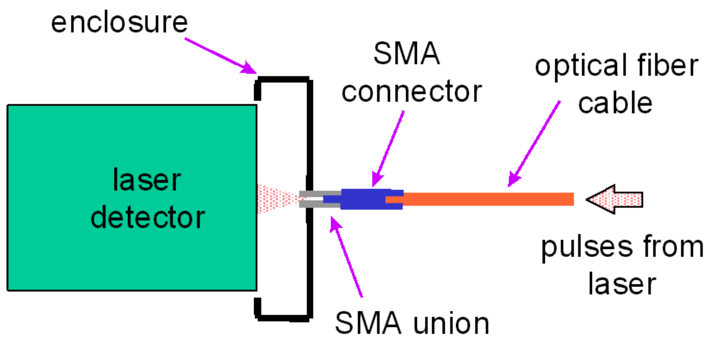

Figure 1. Detector setup for measuring light pulses from the laser as they exit the fiber cable at the beamline. The cable's SMA connector screws into the SMA union, attached to the front of the detector enclosure.

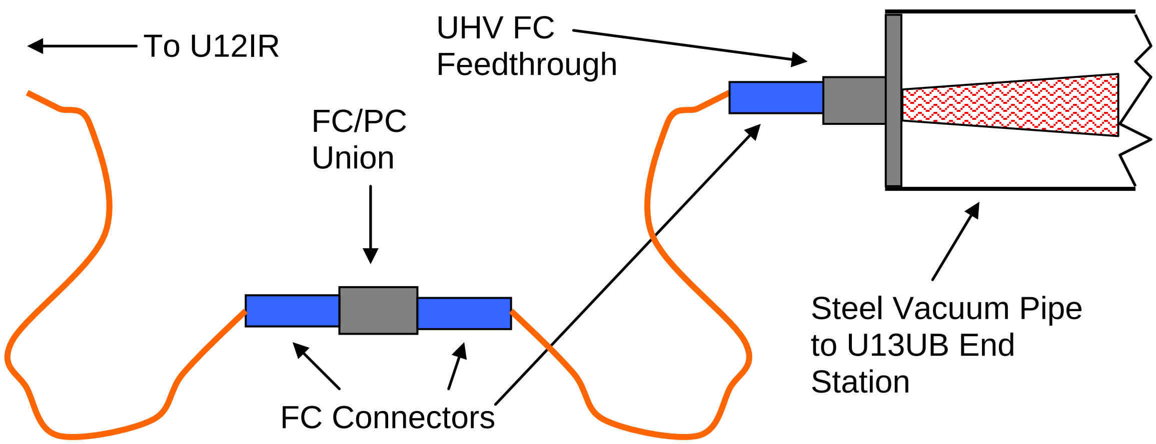

Figure 2. Setup for connecting light distribution fiber to U13UB end station.

A.3.1.4 Light Distribution and Containment at U13UB

The generic layout of U13UB for this experiment is shown below in Figure 3. Whenever Class 4 laser radiation is present at U13, all viewports on the "laser beamline" and the end station will be covered.

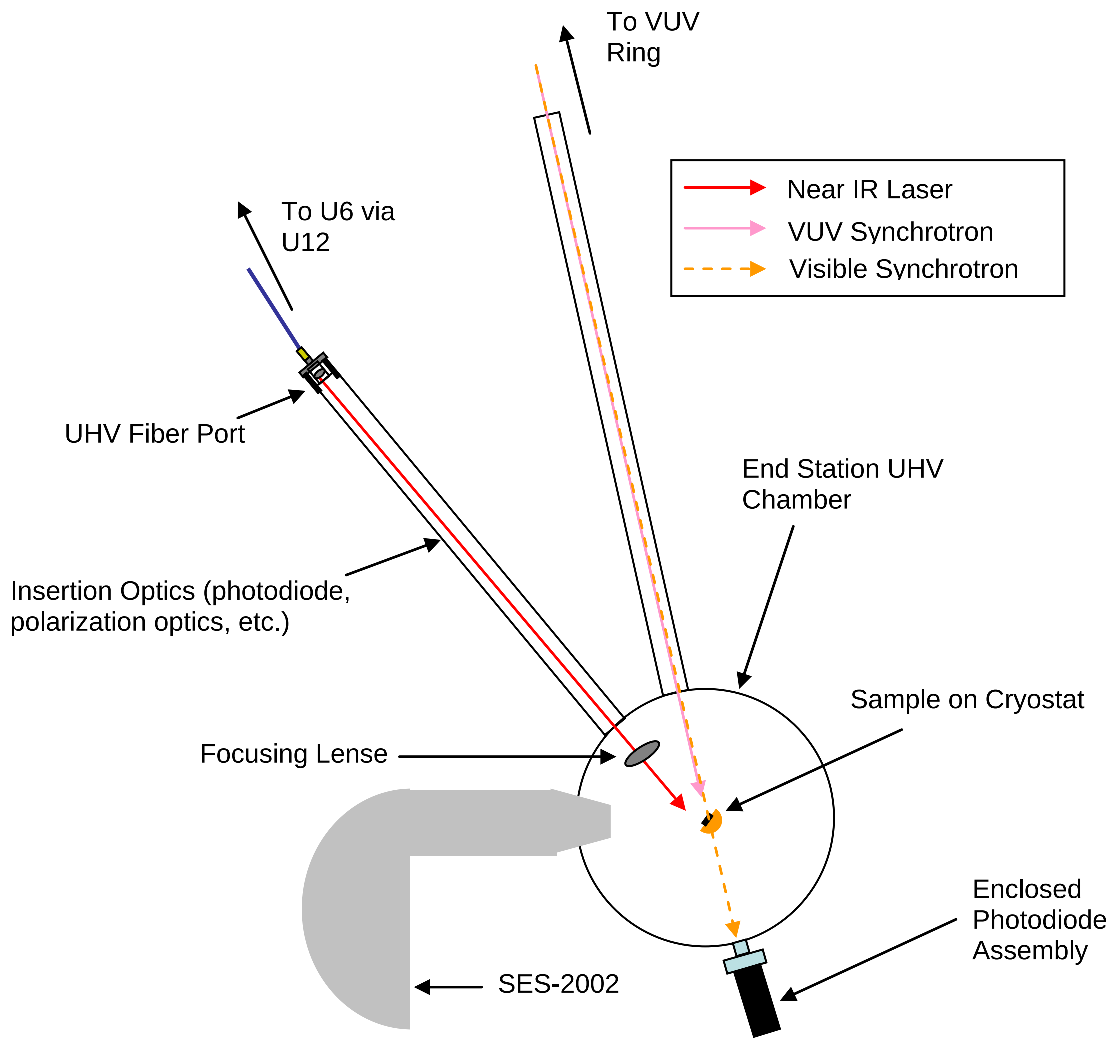

Figure 3. Generic setup at U13UB for ar2ppe. The "little beamline" is the laser beamline.

A.3.1.5 Other Potentially Hazardous Light at U13UB End Station

In order to use the VUV pulses emitted by the synchrotron to perform timing experiments it is necessary to measure the arrival time of the pump (laser) and probe (ring) pulses in the vicinity of the sample. The easiest way to measure the arrival time of the VUV pulses from the ring at the U13UB end station is to utilize the visible portion of the synchrotron radiation that is specularly reflected off our monochrometer near normal incidence. This is the same zero order (ZO) light we typically use for sample alignment in our end station. For this experiment, a lens tube (Thorlabs, SM1) will be attached to the glass view port from which the ZO light escapes (Figure 3). At the front end a lens will focus the ZO light onto a fast photodiode which will be mounted at the back end of the tube in a light-tight fashion. The whole assembly can be translated a few millimeters in the plane orthogonal to the ZO light to position the photodiode at the exact refocus of the ZO light. This arrangement is very adequate and completely light-tight.

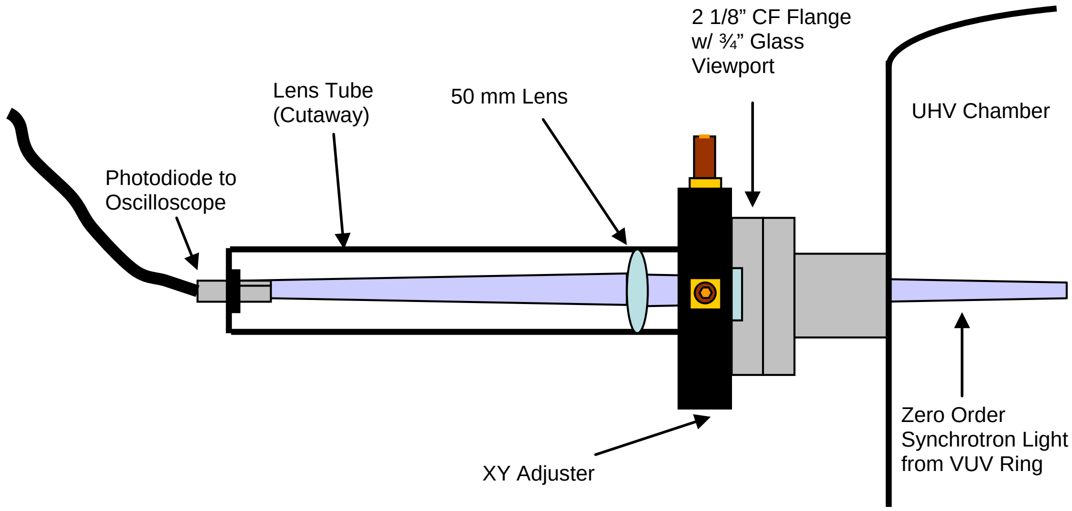

Figure 4. Safe ex-situ detection scheme for zero order light at U13UB

A.3.2. Operations and Procedures

A.3.2.1 Vacuum Ops

By instruction of the vacuum operations group the laser beamline can be interlocked to the U13UB beamline with a Pfeiffer cold cathode gauge and controller. The interlock will be armed and the pressure kept below a setpoint of 10^-9 Torr before both the VUV and laser beamlines are opened to the end station. This is to prevent any possible contamination of the VUV ring by an accident involving the UHV FC fiber feedthrough.

A.3.2.2 Laser Containment

The laser is contained by the stainless steel UHV laser beamline and end station. Laser light can only enter the main chamber coming to a focus at the center of the chamber (18" Diameter). The chamber itself is the backstop. All viewports will be covered while laser radiation is present or imminent. Even reflected radiation will also be very defocused by the time it nears the chamber walls. The shutter in front of the laser at U6 will only be opened when the system is completely contained.

A.3.2.3 Laser Alignment and Focus

We adopt the procedures laid down in Appendix A below, "Alignment Guidelines". In short, we will use a red (wavelength <700 nm) Class 2, cw laser to perform alignment at U13. The laser light will be launched into a fiber by either by a device similar to that pictured below (Figure 5) which completely contains and controls the laser output or by a free space laser inside the U6 hutch. The light is focused with an adjustable 50 mm lens mounted in the chamber. During alignment, when viewports are open, laser warning signs provided by the LSO will be posted in the vicinity. The alignment itself is performed with the micrometer actuated tip-tilt device on the end of the laser beamline to which the fiber feedthrough is mounted.

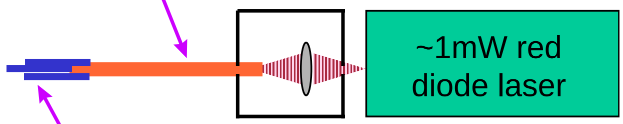

Figure 5. Contained fiber laser launcher.

A.3.2.4 Timing

Relative timing between the pump (laser) and probe (ring) pulses is determined by simultaneously measuring the photocurrents of the fast photodiode mounted on the side of the chamber (Section 1.5) and one can be attached to the light distribution fiber (Section 1.3). The different distances to the sample position are can be calibrated out with appropriate cabling from the detectors to an oscilloscope.

A.3.2.5 Data Collection

When all the above in this section has been accomplished -- vacuum requirements, light containment, alignment and timing calibration – data collection proceeds as listed in the current non-laser SAF for regular ops at U13UB. The operation of the laser itself is performed in U6 and at U12IR as outlined in the documents governing safe operations at those work stations.

Appendix B

Overall Laser Alignment Guidelines

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. Consider having someone present to help with the alignment.
3. All equipment and materials needed are present prior to beginning the alignment
4. 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.
5. Persons conducting the alignment have been authorized by the PI
6. A NOTICE sign is posted at in the area during alignment. Portholes are covered and labeled appropriately.

Alignment Methods to be used for this laser

1. There shall be no intentional intrabeam viewing with the eye.
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. 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 as much as practical, beam stops are secured.
5. Areas where the beam leaves the horizontal plane shall be labeled.
6. Any stray or unused beams are terminated.
7. 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.
8. 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.

B.1

U6 and IR Beamline Laser Operations: Safety Considerations

- All visible alignment at the infrared beamline is to be completed with ANSI hazard class 2 beams. No eyewear is required. A 0.9mW red diode laser with optical fiber coupler is provided for this purpose.

- Once the system is aligned, all ports at the Infrared Beamline sample compartment or cryostat must be covered before the ANSI hazard class 4 beam is brought from the U6 laser hutch enclosure through the reinforced optical fiber to the beamline. A separate shutter (the laser-fiber shutter) in the U6 laser hutch enclosure is located upstream of the fiber coupler for this purpose. A shutter control panel with closed shutter signal indicator is located at the beamline.

- All view ports on the IR Beamline must remain covered whenever the class 4 beam is illuminating the sample compartment / cryostat. FULL CONTAINMENT of the Ti:sapphire laser beam must be maintained at ALL TIMES.

- All fiber optic cables must be labeled with standard laser warning signs (supplied by the BNL Laser Safety Officer) at intervals sufficient to provide adequate warning to anyone approaching the cable.

- Anyone operating the laser system within the U6 laser hutch enclosure involving the class 4 beam must:

  - Complete the BNL web based laser safety training
  - Complete the system specific training requirements
  - Complete the required medical eye exam
  - Read this document
  - Be included on the list of qualified operators
  - Be approved for operation by Larry Carr

- Anyone involved in the measurement at the Infrared Beamline must:

  - Complete the BNL web based laser safety training
  - Be listed on the relevant SAF (which includes the BLOSA requirement)
  - Understand the requirements for full containment of the Laser Beam at All Times.
  - Follow the instructions of the Authorized Laser Operator for tasks related to the containment system (e.g., changing samples, opening and closing the laser-fiber shutter from U6, changing the fiber from the sample compartment to the diagnostic detector).

B.2

U13 Safety Considerations

- All alignment within the U13 end chamber is to be completed with ANSI hazard class 2 beams. The area is to be posted with a standard laser caution sign. The alignment operation must be constantly attended whenever the laser beam is on. No eyewear is required.

- Once the system is aligned, all ports on the U13 end chamber must be covered before the ANSI hazard class 4 beam is brought into the chamber. Aluminum foil is acceptable. The area is to be posted with a standard laser warning sign and be under constant supervision whenever the class 4 beam is illuminating the chamber.

- All view ports on the U13 must remain covered whenever the class 4 beam is illuminating the chamber.

- All fiber optic cables must be labeled with standard laser warning signs (supplied by the BNL Laser Safety Officer) at intervals sufficient to provide adequate warning to anyone approaching the cable.

- Anyone operating any part of this laser system involving the class 4 beam must:

    - Complete the BNL web based laser safety training
    - Complete the system specific training requirements
    - Complete the required medical eye exam
    - Read this document
    - Be included on the list of qualified operators
    - Be approved for operation by Larry Carr

Appendix C: Interlock Systems for Laser Hutch Enclosures

C.1 U6 Laser Hutch Enclosure: Personnel Protection Interlock Description and Operation

C.1.1 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 dumps the interlock and disables the laser power supply (through the interlock on the Verdi main power supply) and closes the shutter. The laser and hutch interlock can not be operated until the interlock is reset by an authorized operator. The Emergency Stop button remains depressed until released by twisting the button.

C.1.2 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 completed and the interlock system engaged (Interlocked sign on, area secure light on).

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 secure, the “Interlocked” sign will be illuminated and the laser hutch enclosure is enabled for laser work.

C.1.3 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.

C.1.4 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.

C.1.5 Pass Through

A person trained and authorized may enter the laser area with the proper PPE – the laser goggles listed in the SOP - 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. It will illuminate (bright yellow/orange) and you may now open the door for entry. Close the door immediately behind you. Once inside the laser area press the Pass-Through button on the inner control station to turn the Pass-Through off (or wait until it times-out). 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 30 second limit. If the door is open for more than 30 seconds, the Pass-Through function will reset and dump the interlock. The Pass-Through is also used when exiting the area, with the process initiated from the Interlock Control panel located inside the laser hutch enclosure. When pressing the Pass-Through button, the button illuminates to confirm it is active.

C.1.6 Interlock Signs

Located beside the main curtain 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.

C.1.7 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.

C.1.8 Interlock Failure

In the event of shutter failure, e.g. by position sensing conflict or failure of the shutter to close when commanded by the interlock logic, a reach-back will be activated which immediately powers down the (Verdi V-10) laser power supply and closes the shutter on the laser head. The effect is the same as pressing an emergency stop.

C.2 U13 Laser Hutch Enclosure: Personnel Protection Interlock Description and Operation

C.2.1 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 dumps the interlock and disables the laser power supply (through the interlock on the Verdi main power supply) and closes the shutter. The laser and hutch interlock can not be operated until the interlock is reset by an authorized operator. The Emergency Stop button remains depressed until released by twisting the button.

C.2.2 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 completed and the interlock system engaged (Interlocked sign on, area secure light on).

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 secure, the "Interlocked" sign will be illuminated and the laser hutch enclosure is enabled for laser work.

C.2.3 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.

C.2.4 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.

C.2.5 Pass Through

A person trained and authorized may enter the laser area with the proper PPE – the laser goggles listed in the SOP - 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 curtain enter the laser area and close the main curtain. 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 30 second limit. If the door is open for more than 30 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.

C.2.6 Interlock Signs

Located beside the main curtain 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.

C.2.7 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.

C.2.8 Interlock Failure

In the event of shutter failure, e.g. by position sensing conflict or failure of the shutter to close when commanded by the interlock logic, a reach-back will be activated which immediately powers down the (Verdi V-10) laser power supply and closes the shutter on the laser head. The effect is the same as pressing an emergency stop.

Appendix D: Training Checklists

D.1.1

Training Checklist for Full Operation of the U6 Ti:Sapphire Laser

1. ☐ Has read and understands the LSOP applicable to U6 Laser Operations. This includes the usage of protective goggles and glasses with regard to the various laser emissions.

2. ☐ Has completed the current training requirements to be a user/operator of the facilities and equipment in the U6 laser hutch enclosure

3. ☐ Understands the function and location for each component of the laser control system (hutch doors, laser curtains, barriers, fiber systems, beam transport pipes and posted warnings).

4. ☐ Understands and can operate the U6 interlock system.

5. ☐ Understands the function of the U6 laser optical layout, including the purpose and operation of each component and has a demonstrated capability to align the various systems.

6. ☐ Understands the U13 shutter, interlock and beam transport system and how it operates.

7. ☐ Has completed the BNL laser medical surveillance eye exam (or approved equivalent) and had successfully completed the BNL Laser Safety training course.

D.1.2

Training Checklist for <u>Basic Operation</u> of the U6 Ti:Sapphire Laser for Time-Resolved IR Spectroscopy at Beamline U4IR or U12IR

NOTE: This Training authorizes a *Basic Operator* for the following tasks:

A. Engage and disengage the U6 Laser hutch enclosure Interlock System.
B. Power the laser system On/Off
C. Operate the Mira 900P electronic control and adjust the Mira exit slit and tuning micrometer for optimal mode-locking.
D. Operate the Laser Synchronization PC system.
E. Adjust and Measure the laser power entering the Fiber Coupler.
F. Adjust the Pulse Picker control voltage for optimal pulse selection.

A *Basic Operator* is not authorized to modify optical system components or the layout on the U6 laser optical table.

1. ☐ Has read and understands the LSOP applicable to U6 Laser Operations for Time-Resolved Infrared Spectroscopy (Appendix A.1). This includes the usage of protective goggles and glasses with regard to the various laser emissions.

2. ☐ Has completed the current training requirements to be a user/operator of the facilities and equipment in the U6 laser hutch enclosure

3. ☐ Understands the function and location for each component of the laser control system (hutch doors, barriers, fiber system and posted warnings).

4. ☐ Understands and can operate the U6 interlock system.

5. ☐ Understands the function of the U6 laser optical layout, including the purpose of each component.

6. ☐ Understands and has a demonstrated the ability to turn the laser system ON and OFF and the procedure for measuring laser power and adjusting the power.

7. ☐ Understands the U13 shutter, interlock and beam transport system and how it operates.

8. ☐ Has completed the BNL laser medical surveillance eye exam (or approved equivalent) and had successfully completed the BNL Laser Safety training course.

D.2

Training Checklist for Full Authorization of Entry and Operation of the U13 Laser Hutch Enclosure

1. ☐ Has read and understands the LSOP applicable to U6 and U13 Laser Operations. This includes the usage of protective goggles and glasses with regard to the various laser emissions.

2. ☐ Has completed the current training regimen to be a user/operator of the facilities and equipment at U6

3. ☐ Understands the function and location for each component of the laser control system (laser curtains, barriers, beam transport pipes and posted warnings).

4. ☐ Understands and can operate the U13 interlock system.

5. ☐ Understands the function of the U13 laser optical layout, including the purpose and operation of each component.

6. ☐ Has completed the BNL laser medical surveillance eye exam (or approved equivalent) and had successfully completed the BNL Laser Safety training course.

Appendix E: Safety and Configuration Checklists

E.1

Safety Configuration Checklist
U6 Laser System and Hutch Enclosure

This checklist must be completed BEFORE engaging the U6 hutch enclosure interlock system and BEFORE powering the Coherent Verdi pump laser.

1. ☐ Confirm that the entrance door for the U6 hutch enclosure has all the proper Laser Hazard postings in place.

2. ☐ The Verdi-to-Mira beam tubes are properly installed.

3. ☐ The Mira exit shutter is in the CLOSED position.

4. ☐ The Verdi and Mira covers are in-place so that all laser emission will be contained.

5. ☐ The mirror for switching beam out to the U13 shutter is in the proper position.

6. ☐ Any other changes to the optical system on the laser table are noted.

7. ☐ All the required laser safety glasses are in good condition and ready for use.

E.2

Safety Configuration Checklist
U13 Laser Hutch Enclosure

This checklist must be completed BEFORE engaging the U13 laser hutch enclosure interlock system.

1. ☐ Confirm that the entrance to the U13 laser hutch enclosure has all the proper Laser Hazard postings in place.

2. ☐ In the U6 laser hutch enclosure, the mirror for switching beam to the U13 beam transport pipe is in the proper position.

3. ☐ In the U6 laser hutch enclosure, the safety interlock shutter at the entrance to the U6-to-U13 beam transport pipe is in the CLOSED position.

4. ☐ The beam pipe from U6 to U13 is intact and all flange seals are in place (Only for Start of Run).

5. ☐ The curtain dividing U13 A and B is in place and that all three padlocks are secured.

6. ☐ All ports on the U13 end station and laser beamline are sealed and signs are posted demarking the end station as an LCA.

7. ☐ A beam dump is located on the optical bench in U13 immediately after the first on-table mirror.

8. ☐ Any other changes to the optical system on the laser table are noted.

9. ☐ All the required laser safety glasses are in good condition and ready for use.

System Training Log

System Description: NSLS Synchronized Ti:sapphire Laser
Location: U6 Laser Hutch, VUV/IR Experimental Floor, NSLS Bldg. 725
System Owner/Operator: G. Lawrence Carr

This sheet provides an optional **local** record of training for working within a specified Laser Controlled Area (LCA). It should provide information regarding users, required training, date of completed training, and verification by the installation owner/operator that the training has been completed and understood at a satisfactory level by the user. As the system expert, the owner/operator should 'self-train' and log the training on the first line of the form. When new or revised training requirements arise, they can be handwritten into a blank column.

The official training shall be documented on the LS-OJT Form found at: http://www.nsls.bnl.gov/training/Courses/Lasers/

Name/Life No.	Eye Exam	Laser Safety Awareness Training	SOP (LS-ESH-0027) Rev 5	Job Specific Training Full Operations	Job Specific Training Limited Operations	
Owner/Operator (Self Training) G. Lawrence Carr						
User						
Owner						
User						
Owner						
User						
Owner						
User						
Owner						