Laser Safety Guidelines

Before commencing work with Class 3B/4 lasers, you must read this document, and sign the sheet at the end to confirm this, and your agreement to abide by the protocols contained herein.

Purpose and Structure of this document

The principal aim of this document is to outline the elements of good laser practice as they apply specifically to experiments currently being undertaken in the Ultrafast Laser Laboratory. General aspects of laser safety are covered in sections of the manuals accompanying the lasers. You should familiarize yourself with these manuals.

The document is structured as follows: at the top level (this sheet) an overall description is made of laser research activity in this laboratory. The user is then referred to a number of accompanying documents under two headings: Laser types in use and Safety Protocols.

Description of Activity: **Ultrafast Laser Laboratory (<u>Customize this section according to your needs)</u>**

In this laboratory various Class 3B/4 pulsed and cw lasers (see section on Laser types) are employed in a project to investigate atomic and molecular response to strong fields. The experiments are performed on atoms/molecules in the gas phase and utilize vacuum chambers or low pressure gas cells. Depending on the experiment, one or more laser beams of differing wavelengths are introduced into the apparatus and are focussed into the gas target. To facilitate this, laser pulses travel along well defined beam paths that are external to the generating laser enclosures. At stages in the experiment various diagnostics are introduced into the beam paths including energy meters and correlation devises.

Two laser systems are used as part of these projects. The first is a regeneratively amplified ~100 fs pulsed Ti:Sapphire laser. The second is a multi-pass amplified ~30 fs pulsed Ti:Sapphire. The mode-locked oscillators for each system are optically pumped by cw Nd:YVO_4 diode-pumped lasers while the amplifiers are optically pumped using pulsed Nd:YLF diode-pumped lasers. Separate sheets are attached concerning each laser type.

Three types of situation have been identified which require separate safety protocols: setting up, adding new elements to and day-to-day operation of the experiment. Separate sheets dealing with each of these are attached.

Laser types in use

The lasers in use in the Ultrafast Laser Lab are rated Class 3 or 4, and comprise pulsed excimer, cw helium-neon, cw diode, cw diode-pumped Nd:YVO_4, pulsed diode-pumped Nd:YLF, and pulsed mode-locked Ti:sapphire lasers as follows:

Customize this list as required by the laser you use.

Description	Laser type	Manufacturer	Pulse characteristics	Wavelengths	Pulse energies
ps system	Diode pumped Ti:Sapphire	Spectra Physics	1–10 ps, 1 kHz, repetitively pulsed	750–850 nm 532 nm (pump)	1–3 mJ 5 W and 20 W
fs system, 2 such systems in lab	Diode pumped Ti:Sapphire	Spectra Physics	~100 fs, 1 kHz, repetitively pulsed	750–850 nm 532 nm (pump)	1–3 mJ 5 W and 20 W
30 fs system	Diode pumped Ti:Sapphire	home built	~30 fs, 1 kHz, repetitively pulsed	750–850 nm 532 nm (pump)	1–3 mJ 5 W and 20 W
UV pump laser	Excimer	Lambda Physic	17 ns, 1–100 Hz repetitively pulsed	193 or 248 nm	≤150 mJ
pulsed pump laser	Nd:YLF	Spectra Physics	100 ps	532 nm	10 W
cw visible laser	He/Ne Diode Diode-pumped Nd:YAG 1. blue 2. green	Carl Zeiss Lasers 2000 Lasers 2000	cw	632 nm 685 nm 473 nm 532 nm	15 mw 20 mW 3 mw 10 mW

As a general rule all of these laser emissions are capable of causing severe eye damage (BLINDNESS) if viewed directly, or as a specular (i.e., mirror-like) reflection. Control measures (careful planning, beam pipes, blocking of reflections, safety eyewear) must be taken to avoid this!

Authorised users of the above lasers are:

Supervisors: ______________________________

Student: ______________________________

Postdoctoral fellows: ______________________________

Laser technicians: trained technicians from laser companies involved in servicing of laser equipment

Please also refer to the following Appendices in connection with this document:

Appendix 1: **General Overview on Laser Hazard/Risk Assessment**

General guidelines for the safe use of Class 3B and 4 lasers.

Laser safety protocol: Setting up

Definition

Setting up applies to the initial installation of a new experiment, and to major changes such as the addition of a new type of laser system, or, for example, a complete change of beam paths.

Protocol

Planning

- The installation or changes must be discussed with a supervisor (KWK or RRJ) prior to operation of Class 3B/4 laser systems. *Signed record of discussion required.*
- In the case of a completely new experiment, the Laboratory Laser Safety Officer (KWK) must be consulted and invited to visit the site of the experiment. The University Laser Safety Officer (Kristy Davis, kad4t@virginia.edu) may also be consulted. Signed record of consultation required.
- The laser beam paths and associated optics must be planned to minimize the possibility of stray reflections.
- Termination of each main laser beam must be planned.
- Provision of suitable laser safety eyewear must be addressed at this stage.

Initial safety checks

- Before starting the Class 3B/4 lasers, beam paths must be inspected for any objects, which should not be there, and beam pipes should be replaced if necessary. Termination of each laser beam must be checked.
- Laser warning signs must be activated, unauthorised persons excluded and doors closed.
- Alignment may be carried out by one or at most two authorised laser operators. No one else may be present in the vicinity during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear must be worn if practicable. Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear as it would otherwise be impossible to visualize the laser beam on a card. In this case, extra caution must be exercised by the operator(s).

Initial alignment and suppression of stray reflections

- Initial laser beam alignment should be performed with a Class 2 or 1 alignment laser (e.g., He-Ne or small cw diode laser) if possible. Remember that the final beam path may differ slightly due to dispersion (i.e., the beam path may be slightly wavelength-dependent).
- At this stage, each and every optic element in the beam path must be analysed for stray reflections. Initially this can be done by predicting the likely path of specular (i.e., non-diffuse) reflections and the actual reflections of the Class 2/1 alignment laser may also be used to help identify stray reflections.
- Suitable beam blocks, opaque at the appropriate wavelengths, must then be installed to block all these stray reflections.
- ‘Beam pipes’ must be installed at this stage to cover longer runs of laser beam, and especially any beams that leave the confines of the laser table. It is recognized that

there may be some places where beam pipes are inappropriate, e.g. when the distance between optics is very short. Beam pipes should be designed to allow limited access to the beam for alignment checking without removal.

Alignment using Class 3B/4 lasers at low power

- The next stage of alignment using the Class 3B/4 lasers may be carried out only after obtaining the permission of a supervisor (KWK or RRJ).
- Alignment may be carried out by one or at most two authorised laser operators. No one else may be present in the vicinity during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Under no circumstances must direct viewing of the laser beam be attempted even if the beam has been attenuated. There must be no exceptions to this (obvious!) rule.
- All optics must be checked for damage, and stability of optics mounts verified.
- This next stage in alignment should be carried out using the lowest possible laser energy (e.g. operating the excimer at reduced voltage or with an attenuated beam) at which it is possible to visualise the laser beam in an appropriate fashion. The method of visualisation is dependent on the wavelength: for UV or visible light, the beam can be viewed on a fluorescent card. An invisible infrared beam may be visualised using LCD heat sensitive paper or possibly using burn paper, an IR viewer or a laser power meter.
- In the case of UV or IR beams, appropriate laser safety eyewear must be worn during the alignment procedure at all times when the laser pulse energy exceeds the minimum permissible exposure (MPE): note that the eyewear should not block the wavelength-shifted visible fluorescence (UV) or the heat effect on LCD paper or burn paper (IR), which can then be used to visualise the beam.
- Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear, as it would otherwise be impossible to visualise the laser beam on a card. In this case extra caution must be exercised by the operator(s) after appropriate consideration of alternatives and assessment of risks. The laser(s) must be operated below the MPE if possible and in any case at the lowest practicable pulse energy. Blocking of possible stray reflections must be double-checked prior to carrying out this stage.
- When aligning collinear laser beams, the required beam path should be defined using variable diameter apertures (iris diaphragms). Each laser beam can then be individually aligned to the required path, thus minimising the necessity for simultaneous multi-beam alignment.
- Further alignment at full power may be carried out in accordance with the protocol outlined under ‘day-to-day operation’.

Laser safety protocol: Adding new elements

Definition

Adding new elements applies to the introduction of any new optic into the beam path of a class 3B or 4 laser such as a lens or filter.

Protocol

Planning

- The placement of additional optics must be planned to minimise the possibility of stray reflections.
- Beam blocks must be devised to terminate any unavoidable stray reflections.

Initial safety checks

- Before starting the Class 3B/4 lasers, beam paths must be inspected for any objects, which should not be there, and beam pipes should be replaced if necessary. Termination of each laser beam must be checked.
- Laser warning signs must be activated, unauthorised persons excluded and laboratory doors closed.
- Alignment may be carried out by one or at most two authorised laser operators. No one else may be present in the room during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear should be worn if practicable. Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear as it may otherwise be impossible to visualise the laser beam on a card. In this case extra caution must be exercised by the operator(s).
- All optics must be checked for damage, and stability of optics mounts verified.

Initial alignment and suppression of stray reflections

- Once a new optic is in place, initial alignment should be performed with a Class 2 or 1 alignment laser (e.g., He-Ne or small cw diode laser). For simple optics it may be judged sufficient to proceed to the next step without using a Class 2/1 alignment laser.
- The new optic element in the beam path must be analysed for stray reflections. This can be done by predicting the likely path of specular (i.e., non-diffuse) reflections. The actual reflections of the Class 2/1 alignment laser may also be used to help identify stray reflections.
- Suitable beam blocks, opaque at the appropriate wavelengths, must then be installed to block all these stray reflections.
- Any effect ‘downstream’ of the new optic must be checked. ‘Beam pipes’ should be re-installed at this stage.

Alignment using Class 3B/4 lasers at low power

- This may now be carried out in accordance with the procedure outlined under ‘setting up’ with the exception that explicit permission of a supervisor is not deemed necessary for addition of a simple optical element. (Anything more complex must be taken as ‘setting up’ and the protocol followed accordingly.)

Laser safety protocol: Day-to-day running

Definition

Day-to-day running applies to the operation of Class 3B/4 lasers under all circumstances except setting up or addition of a new optic element. It includes initial, minor realignment of laser beams at the beginning of an experimental run and 'tweaking' of alignments during an actual experiment.

Protocol

Initial safety checks

- Before starting the Class 3B/4 lasers, beam paths must be inspected for any objects, which should not be there, and beam pipes should be replaced if necessary. Termination of each laser beam must be checked.
- Laser warning signs must be activated, unauthorised persons excluded, and laboratory doors closed.
- Alignment adjustments may be carried out by one or at the most two authorized laser operators. No one else may be present in the room during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear should be worn if practicable. Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear as it would otherwise be impossible to visualise the laser beam on a card. In this case extra caution must be exercised by the operator(s).
- All optics must be checked for damage, and stability of optics mounts verified.

Check using Class 3B/4 lasers at low power

- Before turning on full power, the beam path of each laser must be verified in turn, using the lowest possible pulse energy and visualizing the beam in an appropriate fashion (e.g., on fluorescent card).
- Under no circumstances must direct viewing of the laser beam be attempted even if the beam has been attenuated. There must be no exceptions to this (obvious!) rule.

Minor realignment ('tweaking') with lasers running at full power

- During an experimental run, it will sometimes be necessary to re-optimize the alignment to recover lost signal. Of necessity, this can only be carried out at full power, with all lasers on. Extra caution must therefore be exercised.
- All beam guards/pipes and blocks for stray reflections should remain in place during this procedure. Beam pipes should be designed to allow limited access to the beam for alignment checking without removal.
- It is especially important to wear appropriate laser safety eyewear when visualizing laser beams at full power. As before, in a visible or multi-wavelength experiment this may not be practicable, and extra caution must therefore be exercised.
- It may be possible (and indeed, preferable) to apply minor 'tweaks' to the alignment using the experimental signal as a guide. In this case it is not necessary to visualize the laser beams.
- If it is absolutely necessary to visualize the laser beams, e.g. to optimize beam overlap, this may be done by the appropriate method (fluorescent card etc), but this should be avoided if possible e.g. by the use of iris diaphragms.

Laser safety protocol: Maintenance

Definition

Maintenance applies to all operations inside the laser enclosure. It includes activities such as the removal and reinstallation of optics for cleaning, the changing of laser dyes, the changing of flashlamps, and the installation of new optics inside the laser cavity. Entry into the laser enclosure potentially exposes the laser worker to additional non-optical hazards, for instance those associated with high voltages, and toxic chemicals, in addition to accessing high energy laser beams that are normally enclosed. The activities are very diverse, and specific protocols will need to be prepared for each laser, this document provides some general guidelines on the planning of *Maintenance*.

Protocol

Planning

- Before commencing the maintenance, the manual for the laser system should be consulted, to identify the recommended procedure.
- In the case of anything other than routine maintenance, and/or when the laser manual does not give a procedure, the advice of a laser technician should be sought. Some procedures should only be conducted by an experienced laser technician.
- The hazards associated with the procedure should be assessed, the control measures reviewed, and the conclusions recorded. In the case of some regular maintenance procedures (such as changing the dye solution in a dye laser), reference to an existing protocol may well suffice.
- Maintenance involving the alignment of a laser beam inside a laser enclosure, for instance introducing the pump laser into a dye laser, can lead to an increased laser radiation exposure risk, since part of the beam path of a normally enclosed, and potentially very high power beam is likely to be open. The protocol for *Setting Up* should be consulted.

Appendix 1: General Overview on Laser Hazard/Risk Assessment

Class 3B and Class 4 lasers are capable of causing eye injury to anyone who looks directly into the beam or its specular reflections. Diffuse reflections of a high-power laser beam can also cause permanent eye damage. High-power laser beams can burn exposed skin, ignite flammable materials and heat materials that release hazardous fumes, gases, debris or radiation. Equipment and optical apparatus required to produce and control laser energy may also introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, other forms of radiation, flammable materials and toxic fluids. Each proposed experiment or operation involving a laser must be evaluated to determine the hazards involved and the appropriate safety measures and controls required.

Initial Training

A discussion lead by the faculty supervisor provides basic instruction in laser hazards and their control. All laser workers must also read any and all safety literature provided by the manufacturers of the lasers used.

Hazard Analysis

Before the appropriate controls can be selected and implemented, laser hazards must be identified and evaluated together with non-beam hazards that may be present. The laser's capability of injuring personnel, the environment and the way in which the laser or lasers are to be used needs consideration.

Laser Controls

The simplest rule to follow to avoid eye injury is not to look directly into a laser beam or its specular reflection, regardless of the laser's power or classification or the laser eyewear you may be wearing.

When it is not practical to fully enclose the laser beam path, the non-enclosed laser beam, any strong reflections (≥ Class 1 MPE) and any strong transmissions through mirrors must be terminated at the end of their useful paths using devices such as backstops, shields, or beam dumps. The addition of beam-stopping panels to the sides of optical tables is recommended as a general safeguard against inadvertently misaligned beams.

The laser system must be securely mounted to maintain the beam in a fixed position during operation and to limit beam movement during adjustments. Beams should not be directed toward entry doors. Primary beams and dangerous reflections must be enclosed or confined to a well-defined area of use.

Reflection Control. Wherever possible materials with a low reflective coefficient that diffusely reflect laser radiation shall be used in place of specularly reflective surfaces. (Typical black anodised surfaces reflect more than 10% of incident light.) Specularly reflective surfaces that are needed in the vicinity of beams must be enclosed or shielded to minimise personnel exposure. Non-reflective tools should always be used. Jewellery and other reflective personal items should be removed during laser alignment or other work near laser beams.

Laser accidents

Some common unsafe practices that are causes of preventable laser accidents are:

- Not wearing protective eyewear during alignment procedures.
- Misaligned optics and upwardly directed beams - pay particular attention to periscopes, and reflections from windows and beam splitters/combiners.
- Improper methods of handling high voltage.

- Available eye protection not used.
- Lack of protection from non-beam hazards.
- Failure to follow safety protocols.
- Bypassing of door interlocks and laser housing interlocks.
- Insertion of reflective materials into beam paths.
- Lack of pre-planning.
- Operating unfamiliar equipment.
- Wearing the wrong eyewear.

Laser alignment

It has been reported that some sixty percent of laser accidents in research settings occur during the alignment process.

Laser alignment guidelines to help prevent accidents should include:

- Restricted access, no unauthorised personnel will be in the room or area.
- Laser protective eyewear will be worn, where practicable.
- Class 3B/4 laser users must have received appropriate training and instruction.
- The individual who moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.
- To reduce accidental reflections, watches and reflective jewellery should be taken off before any alignment activities begin.
- Beam blocks must be secured.
- Check the stability and rigidity of all optical mounts.
- When the beam is directed out of the horizontal plane, it must be clearly identified.
- A solid stray beam shield must be securely mounted to prevent accidental exposure to the laser beam.
- All new laser users must receive an orientation to the laser use area by an authorised laser user of that area.
- The lowest possible/practical power must be used during alignments.
- When possible, a coarse alignment should be performed with a HeNe or cw diode alignment laser.
- Have beam paths at a safe height, below eye level when standing or sitting. Not at a level that tempts one to bend down and look at the beam.

Controls for Hazards in Laser Area

Many hazards (other than laser radiation) that can be found in the laser area must be adequately assessed and risks controlled. Hazards include electrical equipment and systems, lighting, pressure vessels and systems, ionizing radiation, hazardous materials, non-coherent radiation, dyes and dye solutions.

Maximum Permissible Exposure Calculations

The main criterion for assessing the optical safety of a given situation is the maximum permissible exposure (MPE). The MPE is that level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects. The MPE levels represent the maximum level to which eye or skin can be exposed without consequential injury immediately or after a long time and are related to the wavelength of the radiation, the pulse duration or exposure time, tissue at risk and, for visible and near-infra-red radiation in the range 400 nm to 1400 nm, the size of the retinal image. MPE levels are specified in clause 13 of BS EN 60825-1:1994 Safety of laser products, Part 1 Equipment classification, requirements and user's guide; this is also reproduced on pages 36-40 of the CVCP Notes of Guidance Part 2:1 Lasers revised 1992. LaserSafe PC is a software package that can be used to assess the hazards of a given situation. This package can calculate the MPE. Excess that can be used to give an indication of the relative safety. Planned ocular exposure to laser light should not exceed the MPE.

In carrying out a risk assessment for the optical hazard, it is important to know of the effects of laser radiation on biological tissue. These are described in Annex B of BS EN60825-1: 1994 and the CVCP guidance booklet, pages 1 to 10. For the purposes of categorising potential injuries the following can be taken as an approximate guide:

SEVERITY OF INJURY can be classified as:

(a) No Injury: Exposure below the MPE.

(b) Minor Injury: Ocular exposure up to 10 times the MPE and skin exposures up to 100 times the MPE (Injuries will normally be reversible).

(c) Major Injury: Ocular exposure in excess of 10 times the MPE and skin exposures in excess of 100 times the MPE (Injuries will normally be irreversible).

(d) Death: Injuries resulting from laser exposure are not normally considered life threatening. Exposure to associated non-optical hazards, such as high voltages, and toxic chemicals, may sometimes have fatal consequences.

Whenever there is a risk of laser exposure to levels above the specified MPEs, safety eyewear is one of the commonest and a very important element of personal laser protection. Safety eyewear should be regarded as a last line of defence against exposure to laser radiation, to be adopted only after a full safety evaluation has been carried out and other means of affording protection have been considered. Its use should not be regarded as a convenient alternative to proper engineering controls or thorough hazard assessments. Protection by safety eyewear is effected by incorporating optical filters to reduce the level of eye exposure for a specified wavelength and power or pulse energy, to below the limiting MPE. The filters required to do this are specified by a quantity called Optical Density (O.D.); this is defined as the logarithm (to the base 10) of the ratio of incident power to transmitted power. Hence, a filter of Optical Density 6 will transmit 1 μW of an incident 1W beam. LaserSafe PC provides a Nominal O.D. result, for any given situation as a guide to the choice of protection in that situation. Eyewear providing a smaller level of O.D. will not offer sufficient protection, a larger value of O.D. is generally to be preferred. When choosing the eyewear, it is important to consider not only the ability of the eyewear to attenuate the incident radiation but also to have a damage threshold high enough to withstand the maximum possible exposure long enough for avoiding action to be taken. Safety eyewear must never be relied on to provide protection against deliberate exposure to a laser beam but should be regarded as a means of providing some protection against accidental exposure.

Signature Sheet

This sheet must be signed by all workers before commencing work with Class 3B/4 lasers.

By signing below, you confirm that you have read this document, and you agree to abide by the protocols and guidelines contained herein.

Name (in block letters)	Signature	Date