

## Memorandum

To: Members of the Meyer and Fraden research groups  
From: Robert B. Meyer  
Date: June 12, 1998  
Subject: **Visible radiation CW laser usage; laser power of 15 mW or less**

This document is specific to the use of low power class III lasers. It is to be read after the researcher has studied the general information and guidelines presented in the Brandeis University Laser Safety Handbook.

These lasers are classified as class III, covering visible radiation CW lasers from 1mW to 500 mW. They are clearly near the lower power limits of this class (sometimes with a separate designation); this reduces risks, but direct entrance of this power laser beam into the pupil of the eye can do permanent damage. These lasers do not present a threat of skin damage or fire hazard. The main point addressed by this document is that the generally recommended safety procedures for this class include important safeguards that make research activities involving construction or modifications of optical systems especially difficult. Since most of what we do in the laboratory is working with experimental systems, rather than utilizing well established systems for applied research, we must observe a set of safety procedures that are quite different from those applicable to established systems used in applied research.

Two major safety procedures for class III laser systems are enclosure of the laser beam in opaque housings, and the use of protective eye-wear that makes the laser beam invisible. The difficulty in working with experimental systems is that these procedures that are not practical in situations in which one is constantly rearranging optical elements and observing how the beam is aligned. If one had to use rigidly supported tubes to enclose the laser beam, every time the optical system was changed, it would require rearrangement of tubes. This is simply so cumbersome that it leads to errors and invites researchers to quit using the tubes. It is therefore more effective to admit that the tubes are impractical, and develop safe methods for working without them. The eye-wear issues are similar. Because protective eye-wear makes the beam invisible it is frustrating to use, and again invites researchers to avoid using it. In fact this leads to many accidents. Even with proper use of eye-wear, because the beams are invisible, one may inadvertently create a dangerous situation while constructing an optical system that causes an accident as soon as the eye-wear is removed. Again, it is a more effective strategy to admit that the eye-wear is not practical, and replace its use with other safety procedures. This is an acceptable approach for these low power visible class III lasers, while it is not always acceptable for higher power lasers or ones producing invisible radiation.

Since one is giving up these two important safety measures, one must replace them with equally effective ones. The goal of these alternative procedures is to prevent laser beams from entering the eye by confining the beams to a well defined work area, and by developing a set of guidelines for working with experimental optical systems. The general procedures are based on common sense and caution, along with constant awareness that the laser beams and optical elements are exposed, and new arrangements make each situation possibly unique. This means that one cannot count on laser beams being in the optimum configurations for safety at any time. It is up to each researcher to be aware of his or her own safety and the safety of others in the area.

### General procedures:

Only researchers who have read the instructional and laser safety materials and had their base-line eye exams are authorized to use optical systems involving lasers. This means that new-comers or visitors to the lab may not turn on lasers, handle the optics, rearrange optical elements, make adjustments to systems, or perform any related activities that might expose themselves or others to the laser beam. It is the responsibility of each authorized researcher to see that this rule is enforced. There is to be no casual use of lasers by researchers or others in the laboratory.

First, some very general instructions: Do not wear reflective jewelry when working with laser beams. Flat reflective wrist watch faces and any mirror-like surfaces are especially dangerous, since they can reflect laser beams at random angles. Whenever possible, work in a normally lighted room. This keeps the pupil diameter of the eye small, limiting the possibility of dangerous laser beam power reaching the retina. It also helps avoid other accidents due to poor visibility. When more than one person is working on an optical system the danger increases. Extra precautions, especially communications, must be used, since one person may change something while another is unaware that the change is taking place. For instance, do not turn on a laser unless everyone knows you are doing so, and takes precautions to avoid the laser beam.

When beginning to work with an optical system, before turning on a laser, it must be securely mounted on the optical table or bench, and oriented so that the beam is approximately horizontal, well below eye level. No operating laser is to be moved from place to place; only small adjustments should be made with the laser operating. Before turning on the laser, anticipate where its beam will travel, and place an absorbing (flat black) beam stop to terminate the beam at a reasonable distance from the laser in the work area of the optical bench or table. At these low laser powers, simple flat black absorbing surfaces are the simplest way to terminate unwanted laser beams; no fire hazard will be involved. Be sure that when turned on, the beam will not reflect off of some optical element or shiny surface toward anyone's eyes. Have a clear idea of the defined work area for the optical system, with the goal of confining the laser beams to this area. This

includes the lateral definition of the system, and equally important, its vertical extent; upward directed laser beams are especially dangerous.

Before building or modifying an optical system by adding, moving, or adjusting optical elements, if at all possible, solidly mount a partially absorbing filter in the laser beam path, ideally at the output point of the laser, to limit laser power beyond the filter to below 1 mW. This restricts the laser power to a range in which the normal aversion response of the human eye will limit exposure to the direct laser beam to less than 0.25 second, which is usually sufficient to prevent permanent eye damage. Only remove this limiting filter when higher beam power is needed. Be sure that when the filter is removed the laser beam direction is unchanged, and only the power is increased. Be sure to check for previously unobserved low power reflected beams that become visible at higher power; block all reflected beams to keep laser beams within the defined work area.

When placing or moving optical elements that might affect any laser beam, always anticipate the consequences of the move, in terms of possible redirection or reflection or unblocking of the laser beam. Be sure that the beam will not travel in the direction of anyone's eyes. When adding or removing or adjusting any optical element in an optical system, verify the direction of any redirected or unblocked laser beams, and be sure that such beams are confined to safe directions. Place absorbing (flat black) beam stops where required. Also place aperture stops where possible, to limit the range of motion of any adjustable laser beam, so that once the beam leaves its useful range of directions, it is blocked by an absorbing surface.

Never examine an optical system by trying to look along a possible light path. Always use a piece of paper inserted into the light path to view the laser beam, rather than either moving your eyes to the area of the light path or using a mirror in the light path. With lasers of this power level, the diffuse scattering of the laser beam from paper will not pose a risk of eye damage.

To the extent possible, design and work with optical systems at a height well below eye level, and keep laser beams traveling horizontally. This reduces the chances of a beam being directed into an eye. Where upward directed laser beams are necessary, exercise extra caution to see that they are carefully confined to a narrow range of directions, and do not lean into the beam path. Terminate upward traveling beams at as low a height as possible, with rigidly fixed optical elements and beam stops, to avoid accidental unblocking of a beam that might be directed toward eyes. Anticipate possible movement of adjustable optical elements and the consequences of such movement, in redirecting or unblocking a laser beam. Place beam stops and limiting aperture stops where needed.

When using a laser in combination with a microscope or telescope, or with any optical instrument usually used with direct viewing with unprotected eyes, take extra precautions. Instruments that gather and concentrate light are especially

dangerous. In general, if possible, replace direct viewing with indirect viewing, by use of a video camera and monitor, or other optical detector, instead of eyes. Before performing any direct viewing by eye, especially on a newly constructed or adjusted optical system involving a laser beam, have the safety of the direct viewing verified by examination by a senior researcher, by indirect viewing methods, by optical power measurements at the viewing point, and by any other means that seem reasonable. For direct viewing situations, it is most important that filters that reduce transmitted laser power to safe levels be permanently incorporated into the optics of the direct viewing position, or eye-point, to protect eyes. In a situation in which direct viewing by eye is unavoidable, never turn on a laser while performing direct viewing; turn on the laser and verify that laser power levels at the eye-points are within safe limits before performing direct viewing. When using adjustable optical elements during direct viewing, verify in advance of any direct viewing that for the full range of adjustment possible, the laser intensity reaching the eye-points is within safe limits.

When preparing to leave an optical system after working with it, be sure that the laser beams, including the primary beam and any reflected beams, are traveling in as restricted paths as possible. Do not allow laser beams to leave the defined work area of the optical system, for instance traveling across rooms or reflecting off of equipment in the area. Then turn the laser off before leaving the area. This will assure that when the laser is subsequently turned on, there will be no unexpected laser beams initially directed in potentially dangerous directions. Also keep the area of the optical system clean and neat. Do not leave any optical element randomly placed in the area of the system, since such an element might inadvertently be moved into the optical system in such a way that it would create a dangerous laser beam when the laser is subsequently turned on.

Never change an optical system that is not being used, by removing or adding elements to it, without verifying that when the laser in that system is turned on, the laser beam will be confined to a safe condition. Typically, "borrowing" an optical element from a system might unblock a laser beam in that system, creating an unsafe condition when the laser in that system is turned on. Likewise, placing an extra optical element in that system might have the same effect. In shared work areas on an optical table, in which there is more than one optical system or more than one laser, this rule is especially important. Likewise, before turning on the laser in any optical system, verify that the system is in a safe condition, so that when the laser is turned on, the beam will be confined to safe directions. Never assume that the system has been unchanged since last used.

Finally, the above general procedures are based on a constant awareness of the potential dangers of the laser beam. They are examples of good safety practices in a research environment, in which optical systems involving lasers are constantly being modified. No list of procedures can anticipate every possible situation in such an environment. It is up to each researcher to learn from these examples and from experience, and to take personal responsibility for developing

new safe practices in new situations. That is the only reliable way to avoid accidents.

Some examples:

Setting up a new system:

Define a work area. Mount the laser oriented horizontally. Mount a limiting filter at its output, checking that light reflected from the filter will not cause a hazard. Place a **beam stop** in the work area to confine the beam. Check on others in the area and when it is safe, turn on the laser. Check placement of the beam stop. Limit the laser power to less than 1 mW. Adjust the limiting filter so that it is precisely perpendicular to the laser beam, so when it is removed the beam direction will not change. Proceed with detailed alignment of the laser beam as needed, and readjust the limiting filter for power and orientation. You are now ready to start adding optical elements to the system.

When adding optical elements, one must be cautious about reflected or redirected beams. Since one is looking at the element while it is added, there is an increased possibility of a redirected beam entering the eye. It is often safest to turn off or block the laser beam while adding the element. Verify the **location** of the element by viewing the laser beam in that area with a piece of paper. Then block the beam or turn off the laser and place the element, mounting it firmly. Check the directions of anticipated reflections and redirections of the beam, and place stops as needed. When adding an element, if possible initially orient it so that any laser beam it redirects will be oriented horizontally. Then, when others know you are about to do so, turn on or unblock the laser without staring at the point where you expect to see the beam. Make adjustments of the element and recheck for safety. When adding an element that creates an upward directed beam, use extra caution.

When finished working on the system, verify that all laser beams are confined to the system's work area. Be sure that all optical elements in the system are securely mounted. Remove any spare optical elements from the area in or near the system. Turn off the laser.

Using a microscope in which a sample is illuminated by a laser.

If possible, do not use direct viewing by unprotected eyes, but instead use a video camera or other detector. If direct viewing by eye is necessary, use all possible precautions. This means double checking each step, and using every precaution you can think of. First, build the optical system observing all the usual procedures, and securely mounting all elements. This includes a solid mount for the sample on the microscope stage. Anything that can be accidentally displaced could cause an accident. If at all possible, have permanently mounted filters in the eyepiece holders of the microscope that limit power entering the eyepieces to safe levels for extended viewing.

Measure the optical power at the eye-points, verifying that is at a safe level. Move any adjustable components, including the sample position controls, through their entire range, verifying that power levels at the eye-points are safe for all adjustments. Check the power meter for proper operation, and do qualitative checks of power at the eye-points, by seeing that no laser beam is visible on a piece of paper held at the eye-points. When beginning direct viewing, move your eyes toward the eye-points slowly, so that at the first sign of any excessive laser power you can withdraw. Do not change the laser power or make any major adjustments of the optical system while performing direct viewing. Be sure that no other person is possibly making changes to the system while you are performing direct viewing. Likewise, do not touch the system while anyone else is performing direct viewing. When leaving the system, be sure the laser is turned off, and the potential beam is blocked from entering the microscope. This is a precaution to prevent any other person who may not be familiar with the system from being endangered by looking through the microscope. Label the microscope to indicate the danger of looking into the eyepieces.