Volume 2
Issue 2

Laser Lessons News Letter

This issue


Photo: James Pryatel

"A fully enclosed laser containment that utilizes interlocked panels is considered an engineered control. One that requires a tool for removal or can easily be removed both are examples of administrative controls. Though, the requirement of a tool for removal prevents the panel from easily being detached, a user action is required to ensure the panel is in place prior to energizing the laser."

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Introduction

Over the past several issues, we have covered such topics as "Biological Effects", "Eyewear", "Non-Beam Hazards", and various near misses and accidents. An important topic generally brushed over, but is vital to overall laser safety is the optical table. This is where the potential for a laser accident begins and ends.

In this issue we will discuss the basics of optical table safety or "Optical Table 101".

Optical Table 101

The easiest indication as to the probability that a laser accident will occur in any laboratory is the condition of the optical table. What does this mean? Purely stated, a well thought out beam-line that is void of unnecessary tools and equipment, and one that controls both primary and scattered light, is less apt to cause an injury than one that is not. This being said, there are components in an optical path that require extra caution and those that can be utilized to prevent the loss of control of a laser beam. We will go through a simple refresher to show the good, the bad, and the ugly of the optical table.

The Good

This section reviews components that you can use or incorporate as part of your optical table layout to contain and control the laser beam. Incorporating many of the following can go very far to prevent an accident from occurring. These will be referred to as "The Good".

Let's start off with working our way from the source (the laser) to the outside (edge) of the table.

Shutters

Generally there are two ways to isolate the optical energy of a laser. One is through removal of the excitation source and the other is shuttering the laser beam. The first is by far the preferred method in terms of personnel safety. It is not always the most preferred though. This is especially true where long warm up times are required for stability or in instances where rapid shut down may damage the laser.

In these cases we would utilize shutter control of the laser. Here, a shutter is placed in front of the laser head, preferably with no gap (See Figure 1 below). The shutter would be connected to a Safety Interlock System (SIS) where unauthorized laboratory access or opening of an enclosure panel would cause the shutter to close, isolating the optical hazard.

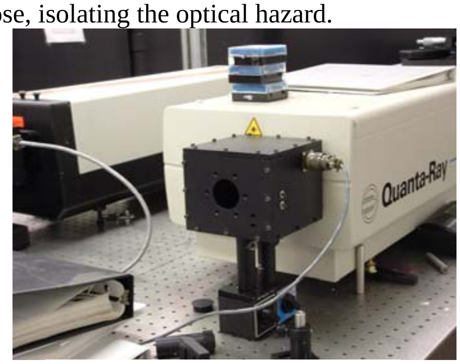


Figure 1. Close Mounted Shutter

Reminder: All Class 3B and Class 4 lasers used at LLNL require SIS control unless special administrative control has been authorized by the Laser Safety Officer (LSO).

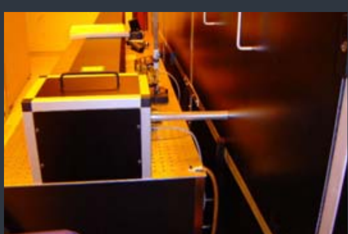
Recently at a DOE lab a modified laser shutter failed when the screws holding the shutter blade fell off. This off-normal event is still under investigation.

Laser Safety Tools:

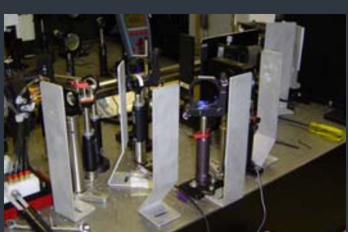
IR Viewer

Aperture

Iris



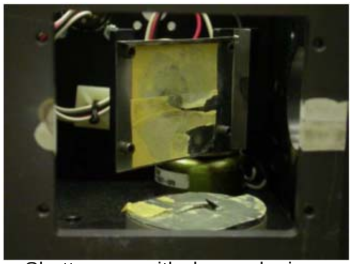
Beam Tube and Enclosure



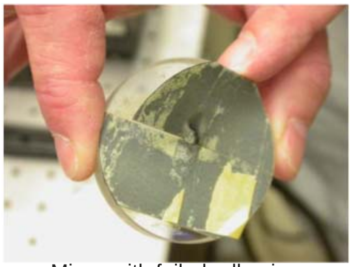
Beam Blocks

Perimeter Guards

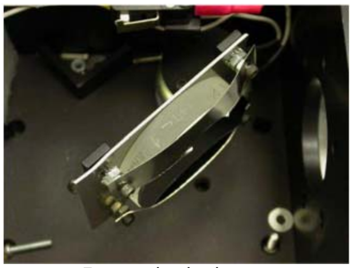
An instance similar to this occurred at LLNL several years ago when a Lab-built shutter failed because the adhesive that held the internal mirror on the shutter arm failed.



Shutter arm with dropped mirror



Mirror with failed adhesive



Reattached mirror

REMINDER: When building or modifying any component on your optical table that is relied upon for safe operations, you should ensure that the item(s) "fail safe". For example a fail-safe shutter is designed such that if power to the unit is interrupted, the shutter closes, inhibiting beam propagation. These devices should be inspected at a frequency that will ensure the items do not fail over time.

Apertures, Irises and Beam Tubes

An aperture, an iris, or a beam-tube are components used to control a laser beam. An aperture is a static opening where laser radiation is allowed to pass. An iris is an adjustable diaphragm used to control the diameter of the laser beam.

Both are used to maintain long beam runs. When used just before and after a change in direction, any misdirected or out-of-aligned laser beam will be well controlled and prevented from leaving the confines of the optical table. These devices can also be used to check and verify the alignment of the system.

A beam tube is usually used when transporting a laser beam from one optical table to another. In this situation, the beam tube should be opaque, interlocked, attached with a tool, or otherwise affixed such that the laser beam is not able to propagate across the tables if the beam tube is missing.

They can also be used to control the transport of a laser beams on the optical table. This may be to preclude the use of laser protective eyewear (LPE) in situations where a specific employed wavelength's hazard is difficult to mitigate by LPE. Beam tube materials need to be selected to be compatible with the laser (fire, laser generated air contaminates, etc.) and sized to allow beam transport without interference.

Barriers and Enclosures

Barriers and enclosures are used to provide protection to workers usually in static laser operations.

REFRESHER: engineered controls require no user interaction to protect while administrative controls require a user to take a procedural action to implement safety.

A fully enclosed laser containment that utilizes interlocked panels is considered an engineered control. One that requires a tool for removal or can easily be removed both are examples of administrative controls. Though, the requirement of a tool for removal prevents the panel from easily being detached, a user action is required to ensure the panel is in place prior to energizing the laser.

To take this a step further, an *enclosure*, one that utilizes interlocks or a tool for panel removal to reveal the higher class embedded laser may be rated as a Class 1 system. A laser *barrier* would define easily removable panels. This type of setup cannot be classified as Class 1.

Additional items normally thought of as barriers are laser beam perimeter guards, curtains, and portal entryway panels.

Viewers and Cards

A viewer is a tool that is used to easily "see" the laser beam. These operate by converting the normally invisible laser beam to a visible wavelength. They are usually of direct or indirect viewers or viewing cards that shift the incoming invisible beam.

Other inexpensive and easily attainable items that can be used to view a laser beam are regular index cards and web or CCD cameras.

Modern video cameras using CCD or CMOS image sensors have a response from the deep violet and near-UV (>350nm) to the near-IR (<1100 nm). This extends to most of the lasers of interest to experimenters except the CO_2 lasers (10600nm). However, it is probably necessary to remove a built-in IR blocking filter to get good IR response.

NOTE: The appearance on a color video monitor of IR well beyond the red-end of the spectrum (~800nm) will likely appear white or even blue-white, not red as might be expected. This may be because the color filters used in the image sensor are dichroic coatings optimized for the visible spectrum and all three (RGB) have high transmittance in the IR.

When using laminated viewing cards, be sure to direct the card down to prevent reflections from travelling across the room. Also, sensor cards should not be used as beam blocks (i.e. turn the laser power down), there should not be burn holes in the card.

The last piece of advice is that LPE is required to be worn whenever using any viewer or card.

Beam Blocks, Perimeter Guards and Dumps

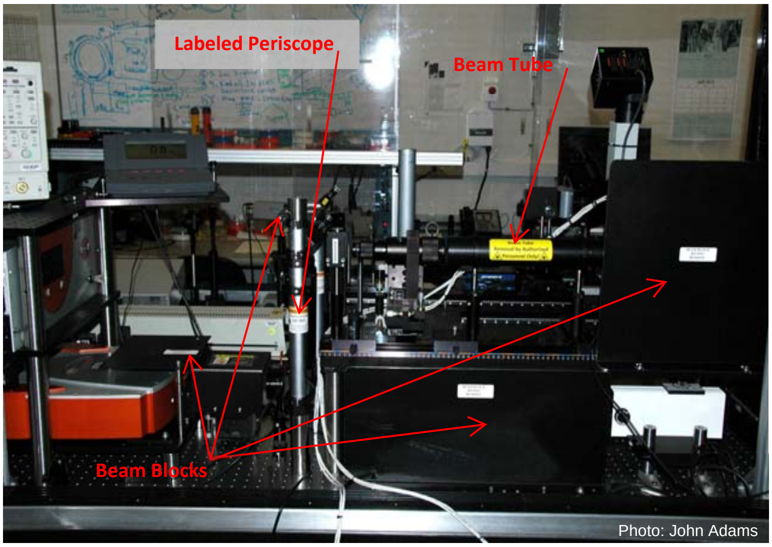
Beam blocks, perimeter guards, and dumps are used to stop the further transmission of the laser beam. Materials used for each can vary greatly. Where a piece of paper would be adequate to block a 10mW laser beam and anodized aluminum could be used to block a 1 watt laser, a much more robust material would be required to block a 100kW laser beam.

When barriers or enclosures are not incorporated, the use of beam blocks around optics or perimeter guards around the optical table is paramount to capturing stray reflections and keeping the hazard on the optical table.

As for beam dumps, commercially available dumps are limited to 10s of kW's average power maximum. Any need greater than this necessitates that the user build their own.

Serious consideration as to material choice is paramount to ensure that the material can withstand the thermal load and will not release toxins or carcinogens when heated. With extremely short pulsed lasers, nano-particles may also be a potential concern.

Beam blocks that have been within the beam path can be extremely hot. Use caution when moving. Besides energy absorption, consideration must also be given to the reflectivity of any material used to block a laser beam. Anodized aluminum is highly reflective to some IR wavelengths.



Well planned and implemented optical layout

The Bad

This section reviews components that are vital to many optical configurations, but may present potential hazards to the user of which they should be aware.

Polarizers

A polarizer is an optical element that is used to transform non-polarized or natural light into polarized light. There are linear, elliptical and circular polarizers.

The bad here is that no matter the type of polarizer used, they all must select a particular polarization state and discard the others. With that being said, rotating polarizers have been involved in more laser injuries than any other type of optic.

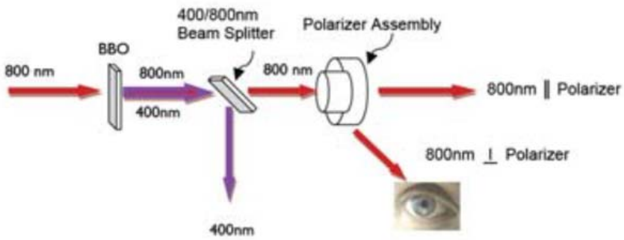
An accident occurred at a DOE lab where a worker was adjusting a rotating polarizer. The individual was adjusting the relative angle between the rotation mount and the polarizer. They accidently uncovered the rejected beam which came out of the horizontal plane of the table and struck the worker in the left eye. The worker was NOT wearing laser protective eyewear (LPE).

Beam Splitters

A beam splitter is an optical device used to separate the incidental beam into two or more separate beams. Though these components may be vital to your optical configuration, they also present potential dangers.

The inherent properties of the splitter require the device to partially reflect the incident beam. This may be potentially hazardous if the user does not account for these reflected beams. Another potential "gotcha" is that cube beam splitters can be inserted incorrectly creating significant unintended dangers.

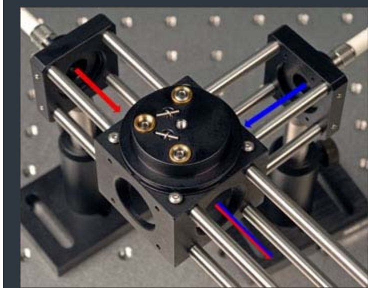
Recently at a DOE lab, a technician was aligning a complete laser system as part of



Laser Safety Gotcha's:

Beam Splitter

Rotating Polarizer



Dichroic Mirror

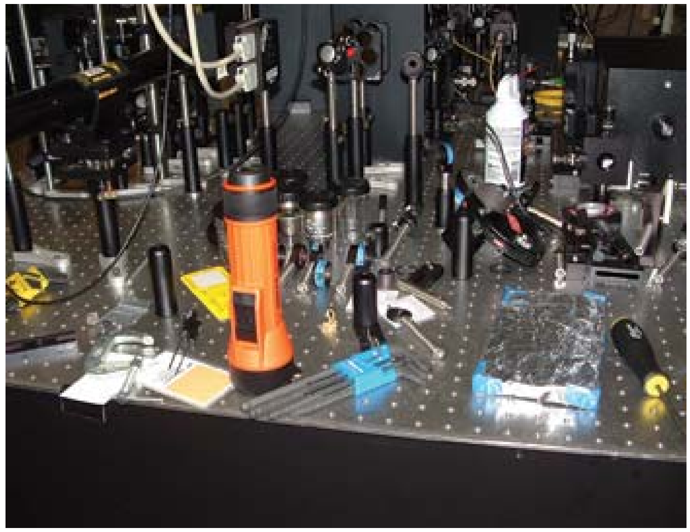
Periscopes

Vertical Optical Table

preventative maintenance. While the worker was troubleshooting a problem, they inserted the beam splitter upside down.

The technician attempted to fire the laser into alignment paper to verify the alignment of the first and second optic. They did not get indication that the beam had reached the paper. Upon inspection, the technician discovered that they had inserted the beam splitter upside down.

Further inspection revealed that the system's telescope and camera were damaged from the wrongly inserted beam splitter and required replacement. Fortunately, there was no injury related to this incident.



Poor Housekeeping on Optical Table

Dichroic Mirrors

A dichroic mirror is one used to selectively reflect light according to its wavelength. These are used in many optical setups and are also used in the application of reflective LPE in dielectric coatings.

Reflectivity of the mirror is highly dependent on the incident angle of the laser beam. The greater the incident angle equates to the more light that is able to pass through the mirror. In very high powered lasers, even a small percentage of leakage (1-3%) is enough to cause a retinal burn. Be cognizant of this when using these mirrors and capture any leakage and scattered light.

The angle of incidence is also particularly important when using reflective LPE. Be aware of this and use reflective eyewear ONLY for the specific wavelengths for which they are designed. This means that if you have a 1053nm laser and reflective LPE rated for an optical density at 1064nm, this "notched" filter more than likely will not protect you adequately.

Periscopes

Periscopes are used to direct laser beams either upward or downward. Many times they are utilized in situations where the scientist has simply run out of real estate on the optical table and builds upward or downward.

These can be a source of misaligned reflections. There may also be light leakage through the mirror. When using periscopes, the use of shields (barriers, beam blocks, beam tubes) and warning labels should be used.

A case history reports that a laser experimental set up was aligned through a polarization rotator periscope where the laser beam was sent across the room to a vacuum compressor. The periscope was aligned only by visual inspection. When the laser was turned on, the beam was transported up to eye level where it struck an individual in the eye. The individual was NOT wearing LPE.

Vertical Optical Table

Vertical Optical Tables are used in situations where fit and function preclude normal horizontal installation. Because this violates the number one thumb rule of laser safety to keep the laser beam out of the plane of the worker while sitting or standing, increased situational awareness and implementation of strict beam controls is vital. If your application involves the use of vertically installed laser tables, ensure that you "know" where the beam is and keep you face and eyes away.

The Ugly

The ugly of the optical table sets you up for the perfect storm. A table that becomes partially an experiment and partially a storage area is enemy number one. The following items have been spotted on optical tables and are housekeeping issues. Are any of these on yours?

- Spare mirrors and mounts. - Mirrors sitting on posts, at beam level, become a serious hazard in the event of a stray beam.
- Solvents and other flammables - Should a stray beam strike these, a serious fire may occur.
- Exposed voltage and non-electrically bonded optical tables - Remember that to this day, there has never been a death related to exposure to a laser beam, but there have been many instances of electrocutions related to laser work.
- Tools and other equipment - Here again you have "stuff" on the table that can interfere with the laser beam.
- Slips, Trips and Falls - Keep aisles around the optical table clear and free of clutter.

Finally the most over looked hazard when performing work on a laser table are people. No matter how safe a system is designed, it is the interaction of the people with the system that ultimately defines the systems safety.

- Clear ALL non-essential, unnecessary and untrained individuals from the area. They will be a distraction at best and more than likely a hazard.
- Instruct anyone else with you as to the hazards of laser light and make sure they understand all of these guidelines.

When you are building a new experimental setup or modifying an existing one, remember to think about what you are placing on the optical table and how you can utilize the good and the bad to prevent the ugly.

I would like to sincerely thank John Peterson who was a contributing author for this issue. Please contact me if you have an idea or would like to contribute to a future issue.

BE SAFE!