Laser Eye Protection for Ultrashort Laser Pulses

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Introduction

Lasers that emit pulses of radiant energy that are nanoseconds in duration (one billionth of a second) or longer are quite common in military, medical, and commercial applications. Laser pulses that last femtoseconds to ten picoseconds in duration are considered ultrashort or ultrafast laser pulses. Lasers that are capable of emitting pulses measured in the picoseconds (trillionths of a second) or femtoseconds (quadrillionths of a second) are becoming increasingly available, reliable, and more affordable. The short pulse duration of such lasers presents unique challenges for choosing personnel protective equipment.

Ultrashort Laser Pulses

Under specific conditions, the high energy per pulse and short pulse duration generates a high peak power pulse. These pulses are capable of causing air breakdown, filamentation, and super continuum generation, or spectrum broadening, making them more hazardous than longer pulse duration lasers.

Currently in the Department of Defense, most lasers capable of producing ultrashort pulses are limited to medical facilities using commercially available systems and research labs using commercially available systems or systems built “in-house” by researchers. These lasers present special challenges to personnel who work with or around them and for laser safety officers responsible for a laser safety program.

Injury Mechanism

Eye injuries from lasers are often due to thermal, thermo-acoustic, or photochemical damage; however, injuries produced by ultrashort laser pulses are caused by different injury mechanisms. Ultrashort pulses can cause shock-waves and bubble formation in the tissues of the eye, which lead to tissue damage (Reference 1).

An injury can occur from an intrabeam exposure or from viewing a reflection of the beam. Most documented injuries from ultrashort laser pulses have occurred when personnel view a reflection of the beam (Reference 2). Exposure to just a single pulse, occurring on the order of a trillion times shorter than the blink of an eye, is all that is needed to cause damage.

A typical scenario of when an injury could occur from a reflection is when a researcher, without appropriate laser eye protection (LEP), is checking the alignment of a laser in an experiment. His/her eyes would be focused on the laser spot on a surface, such as a phosphor card or beam stop, to determine the beam’s position. The reflected beam would cause an injury in both eyes near the center of the visual field of view. It is of utmost importance that personnel wear the correct LEP and do not look over the LEP for a clearer view of the experiment.

LEP

The unique properties of ultrashort laser pulses make it difficult to protect personnel from them. LEP may not provide the optical density (OD) that is specified by a manufacturer for such short pulse durations (References 3 and 4). Several factors contribute to this:

- High peak power: Saturable absorption in the filter material may occur which reduces the OD.
- Broadband emission: Supercontinuum generation converts a narrow wavelength band to a wide wavelength band which might require a broadband filter.

Solutions

In general, most laser injuries occur during alignment of the laser beam. Indirect viewing, such as an infrared camera and monitor, should be used when possible in laser labs so that personnel are not viewing the laser energy directly during alignments. Many common laser wavelengths, including those produced by the Ti:sapphire laser commonly used to create ultrashort pulses, can be viewed with inexpensive webcams or digital cameras. When feasible, alignments should be made with the laser operating at a reduced energy or a longer pulse width.

The preferred method of protection during operation would be to enclose the beam path of the laser when emitting ultrashort pulses. This has the added benefit of protecting the optical components from dust.

LEP is labeled with OD at various wavelengths by the manufacturer; however, these values should not be trusted when using ultrashort laser pulses unless the LEP is specifically designed for such an application. Users with an ultrashort pulse laser and a means to measure its energy can determine the OD of their LEP through measurements but should be aware that damage to the LEP is probable.

LEP, personnel protective equipment, and enclosures should be inspected periodically for signs of damage and replaced if damage from laser strikes is observed.

References

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