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Laser and Acoustic Excitation Safety

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In the course of their employment, nondestructive test personnel may work near or with lasers. Lasers are used to generate and detect ultrasonic waves. Lasers are used in optical methods of nondestructive testing, particularly holography and shearography, as well as for precise measurement of displacement in a wide variety of strain monitoring for structures including critical infrastructure such as road embankments. More often than for inspection, lasers are used for joining and machining operations, including precise etching and cutting. Even inspectors who never use a laser are likely to work around them one day.

Laser Safety

Shearographic test systems are for either portable or fixed production applications. Portable shearography systems can be tripod mounted or configured for on vehicle field inspection. Fixed production systems may use test chambers to allow vacuum stress and scan gantries to inspect large panels or structures. As with all laser devices, exposure of the operator to laser emissions must be controlled and shearography instruments and systems must comply with state and federal laws regarding radiation health.

Laser shearography and holography NDT systems use laser light to illuminate the surface of a test article being inspected. The laser provides a convenient source of monochromatic-coherent light that makes the implementation of shearography and holography NDT possible. With the exception of extremely low powered laser systems, virtually all laser products pose some form of hazard. The most common hazards associated with lasers come from the direct exposure of the eyes and skin to the laser light itself. In the United States, laser systems are classified in accordance with the regulations set forth by the Center for Devices and Radiological Health (CDRH) division of the Food and Drug Administration (FDA), primarily concerned with medical devices. Additional federal, state, and local regulations may also apply to further regulate the use of a laser product for a given application. Many of these secondary regulations are based on classification data provided by the American National Standards Institute (ANSI).[1,2] Both the American Conference of Governmental Industrial Hygienists and the Laser Institute of America provide valuable guidelines.[3,4] In the European community, laser system standards are overseen primarily by the International Electrotechnical Commission (IEC) and the British Standards Institution (BSI).[5,6]

Classes of Lasers

Laser and laser system classifications are divided into four general classifications (Classes 1 through 4) based on levels of increasing hazard. Subclassifications may further define the general hazards associated with a given laser product. Laser classes are based on the wavelength, output power, and whether the laser has been designed to operate in a continuous wave (CW) mode or pulsed mode. Pulsed lasers are designed to release their stored energy in pulses that typically last well under 0.25 s. (Femtosecond pulses are easily achieved with the proper laser system.) For the purposes of most shearography and holography NDT applications, continuous wave lasers are used.

The classification of a laser system is based upon the type and level of exposure an operator would be exposed to during the normal operation and maintenance of their laser system. Based on these conditions, it is very possible that laser systems classified as Class 1, Class 2 or Class 3a may contain Class 3b or Class 4 lasers.

Class 1 lasers or laser systems are generally considered safe because of their low power or because the laser system has been interlocked in such a way as to prohibit operator exposure to laser emissions.

Class 2 laser systems are generally considered safe under most working conditions as the *blink reflex* (aversion response time) of the human eye will prevent damage in the event of an accidental exposure. Caution should be taken however with regards to the intentional long term direct viewing of this laser light and concentrating the power of the laser light with positive magnification optics such as a telescope or magnifying glass.

Class 3 laser systems are typically broken down into two categories, low power (CDRH Class 3a/IEC Class 3r) and high power (CDRH/IEC Class

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3b) systems. Precautions required for the low powered systems are very similar to those associated with Class 2 lasers but with an increase in allowable power output from 1 mW (Class 2) to 5 mW (Class 3a/3r). Care again must be given to intentional direct viewing of the unexpanded laser light and the use of positive magnification optics to increase the power density of the available light.

Class 3b lasers pose a unique category as they range from relatively safe lasers with outputs slightly above the 5 mW Class 3a/3r requirements, to relatively dangerous lasers with outputs up to 500 mW. Class 3b lasers can easily produce burns to both eyes and skin as power levels increase from about 50 to 100mW. The class 3b classification applies to both visible and invisible lasers, thus increasing the potential risk of accidental exposure.

Class 4 lasers and laser systems are considered hazardous for both eye and skin exposure. Additional hazards include fire and the production of airborne contaminants such as ozone. In addition to the increased hazards, use of Class 4 laser systems is generally very restricted and requires medical surveillance for operators with respect to possible eye exposure.

From a practical standpoint, laser systems for shearography and holography NDT systems should be classified so as to provide the most usable system for the operator with the least restrictions. To minimize hazard and restrictions, systems with classification of Class 1, 2 and 3a (3r IEC) are often preferred to those with Class 3b and Class 4 classifications.

Shearography and holography systems classified as Class 1 and 2 laser systems generally do not require any special safety consideration beyond a basic understanding of the safe use of lasers. Under normal working conditions.

Class 3a laser systems extend allowable output emissions of the laser system by five times those of Class 2 laser systems without adding additional restrictions beyond a more in depth knowledge of safe laser operation.

Class 3b and Class 4 laser systems should generally be avoided for all but laboratory or well-controlled environments because of operating restrictions and the need for additional medical surveillance.

When working with any laser system a few common sense rules of laser safety will go a long ways toward establishing a safe working environment:

Common Sense Rules for Laser Safety

Common sense should be applied to laser safety.

- Never stare directly into the operating laser system or at the bright mirrorlike reflections produced by laser light that is reflected from metallic or other highly reflective surfaces. Intentional extended viewing of a laser beam issuing directly from the laser source or indirectly from mirrorlike reflections can cause injury or blindness.
- Avoid unnecessary eye exposure to both direct and reflected laser emissions. When possible, close the shutter of the laser emissions or turn off the laser power when working near the front of the laser system and access to the laser light is not required.
- Do not leave laser systems powered and unattended *or with personnel unfamiliar with basic laser safety procedures*. Turn off the laser power, and whenever possible remove the laser interlock key from Class 3b and Class 4 laser systems to prevent unauthorized access to the operating laser system.
- Maintain laser emissions within a controlled working area. The laser work cell should have interlocks on all doors that enter into the work cell that will automatically turn off the lasers when a door is opened. A "Laser On" lighted sign from an approved source should be installed outside each entrance to alert personnel not to enter the work cell when lasers are in use. All windows for viewing activity in the work cell should have laser-safe glass with regular glass panes installed on both sides to prevent damage to the laser coating.
- Be aware of all stray laser emissions and ensure that they do not pose a hazard to others. Warn bystanders or observers of the presence of laser emissions and possible hazards.
- Do not use viewing optics such as binoculars or magnifiers to view the light from the laser system. These devices can increase the concentration of the laser light. Normal eyeglasses are not dangerous: they merely correct the natural vision of the human eye and do not increase the concentration of the light being viewed. However, normal eyeglasses do not provide protection from lasers that are not eye-safe. When working on an active laser, the technician should always wear laser-safe goggles rated for the class of laser.
- Do not disassemble, override, or otherwise modify safety interlocks and sensors for any laser system, including those used in shearography and holography unless you are a laser trained technician with appropriate safety equipment. The classification of your laser system is based on operator access during the normal operation and maintenance of your laser system. Bypassing interlocks or modifying system enclosures may amplify laser illumination beyond normal for a certified laser product. Modifying the system's optics, interlocks, or enclosures may invalidate the classification of your laser system and place technicians or operators in danger.

Acoustic Hazards

Hazardous levels of acoustic noise are not directly associated with the shearography NDT but may be a byproduct of the stressing methods used

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during its application. Sound levels of 130 dB are currently being used for a number of shearography NDT applications employing acoustic or mechanical vibration stressing. In the case of acoustic stressing, large compression drivers are employed with focused horns to vibrate the test article under examination. Within the United States, noise exposure regulations for industry are defined by OSHA as documented within 29 CFR 1910.95.[7] According to 29 CFR 1910.95, noise exposure to sound levels above 85 dB must be regulated through either environmental controls or the use of personnel protective devices such as ear plugs or ear muffs. Long exposure to sound levels above 85 dB may gradually produce hearing loss.

Sound pressure levels referenced by this standard can be readily measured using inexpensive sound level meters available through many audio and electronic supply houses. The measurements are made using an "A-weighted" – "slow response" setting. Limitations as to the permissible time over which an individual can be exposed to increasing levels of noise are defined by 29 CFR 1910.95 and range from 8 h at 90 dBA to 15 min at 115 dBA. Additionally, no exposure to sound intensities greater than 140 dB must be permitted.

Due to variations in the application of acoustic stressing, a worst case exposure corresponding to the maximum output of the acoustic driver over the expected work period (up to 8 h per day) should be assumed. Noise protection devices should be selected to bring personnel exposure levels to no more than 90 dB (preferably 85 dB). over the course of an 8 h work day. General noise recommendations for acoustic and mechanical vibration stressing include the following.

- Always use the lowest noise level necessary for the inspection being performed.
- Always assume that the noise source is active unless it has been made safe (preferably by removal of power).
- Be conscious of both operator and bystander exposure levels. If personnel other than those performing an inspection are present, ear protection should be provided.
- Warning signs should be posted outside the danger zone to warn people entering the test area of possible high intensity noise.

Closing

In closing, one final warning is necessary as a disclaimer. Lasers are a dangerous technology. Do not assume the precautions in the present article are complete or sufficient. Inspectors must acquaint themselves with all health and safety regulations and guidelines appropriate for the job at hand. Employers should provide workers with all equipment and information needed to work safely. Lasers provide great benefit in manufacturing and testing environments but all precautions must be followed.

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