Health & Safety News

Laser Safety

The last 20 years or so have seen a steady increase in the use of laser technology in conservation treatment projects; it is no longer a surprise to find a laser cleaning system in a conservation studio. Laser cleaning has come a long way since the early 1970s when John Asmus and colleagues tested a pulsed ruby laser on fragile Venetian sculpture. It is amazing to think we are now fast approaching the 50th anniversary of those initial tests which first demonstrated the potential of the technique. Private conservators are also using this technique, with the availability of rental systems making it possible to hire a laser for a particular project.

Generally, the type of laser cleaning systems used in conservation are classified as Class 4 systems, including:

- the NdYAG laser emitting pulses of laser radiation at 1064nm (most common)
- the ErYAG laser emitting pulses of laser radiation at 2940nm (more recent)

Laser System Classifications:

NdYAG = neodymium-doped yttrium aluminium garnet laser
ErYAG = erbium-doped yttrium aluminium garnet laser

Lasers are classified in terms of their wavelength and output power. There are four main categories which define the potential of the laser to cause harm to an exposed person. The classification system is part of European and North American laser safety standards, IEC 60825 and ANSI Z136.1, respectively.

Class 4 means that the direct beam as well as specular (from shiny surfaces) and diffuse reflections (from matte surfaces) pose an optical hazard if they enter the eye. Laser radiation at 1064nm can damage the retina, while laser radiation at 2940nm can cause damage to the cornea. Damage is permanent. Fumes/particulates emitted during the laser cleaning process are also hazardous. Remember also that the laser is an electrical device, so keep it dry and don't go poking around inside if there's a problem!

NOHD and Your Eyes

The Nominal Ocular Hazard Distance (NOHD) – the distance from the laser beam delivery handpiece at which the laser beam can be considered safe – is important. Many lasers incorporate a focusing system inside the handpiece which focuses the beam to a point beyond which it diverges and becomes weaker as distance increases (even so the NOHD for a NdYAG laser can easily be greater than 50m!). The precise value will depend on the characteristics of the laser system being used; collimated beams can have a NOHD of hundreds of meters. It is safest to assume that the beam will present an optical hazard wherever it goes. The NOHD for typical ErYAG laser cleaning systems is generally less than for a similarly powered NdYAG laser, but can still easily reach 10m.

Risk can be reduced to an acceptable level by putting controls in place and by wearing the appropriate laser safety eyewear. Laser safety can be broken down into three main areas of controls:

- Administrative controls;
- Engineering controls;
- Personal protective equipment.

Administrative controls focus on who works with the laser. Any person working with a class 4 laser must be properly trained so that they are aware of the hazards and know how to safely use the laser. Any organization using a class 4 laser should appoint a single staff member to oversee laser safety in that organization; this will ensure that appropriate safety controls are in place, that only trained staff work with the laser, and that those staff are following the safety controls by performing routine and regular checks. A "List of Authorized Users" should be kept.

Fumes and Particles Hazards

The chemical makeup of the fumes and particles and the sizes of particles emitted during cleaning will depend upon what is on the surface of the artwork. Particle sizes will also depend on the wavelength of laser radiation being used and the fluence (energy/beam size) of the laser beam. Sometimes, old coatings can "pop off" in large (mm) flakes, but the ablation process can also generate a range of particle sizes from hundreds of microns to tens of microns, and even sub-micron (in some cases). The material ejected during cleaning may contain particle sizes that can enter the body and particles potentially so small that they pose a risk through skin contact and inhalation. The safest approach is to err on the side of caution and assume that what comes off poses a hazard. The ErYAG laser can also generate particles via ablation but very often it is used to soften and disrupt a surface so that the material can be wiped away. It is sometimes used in conjunction with relatively mild solvents and so the hazards posed by adjunct materials must also be considered as part of the risk assessment.

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Engineering controls involve setting up a controlled area in which laser cleaning can be safely carried out. Ideally, laser cleaning should be undertaken inside a separate room in which the laser beam is confined. If this is not possible, then it will be necessary to erect screens to protect other staff/members of the public from a stray beam. When setting up such screens it is important to consider the potential paths the beam can take during cleaning. For example, is there any chance of the beam striking the ceiling so a reflection could be directed downwards out of the laser cleaning area? If so, could a member of staff/public be exposed to the beam? If possible, then some form of control must be put in place to ensure this does not happen. For example, engineering design might include putting a "roof" over the laser cleaning area or closing off the area to other staff, the public, etc. In addition, warning signs must be posted to ensure that no one can accidentally walk into the laser cleaning area. Also note that laser radiation at 1064nm is transmitted effectively by glass; windows must be covered. Wherever possible, the work should be set up so that the laser beam is not directed towards a door or one of the access points into the laser cleaning area. Extraction equipment should be used wherever possible to collect debris ejected during cleaning.

Personal protective equipment (PPE) is necessary because it is not possible to reduce risk to an acceptable level by using only administrative and engineering controls. Appropriate laser safety eyewear must be worn by the operator and anyone else within the laser cleaning area (including anyone who could potentially be exposed to the laser beam). The level of protection required may differ depending on the specifications of the laser itself (wavelength, pulse duration, pulse energy, repetition rate, etc.). The laser manufacturer/supplier will specify the correct eyewear and will usually supply the eyewear with the laser. If in any doubt about what to wear, ask. Also, a respirator may be necessary to prevent inhalation of the ejected material, depending on the effectiveness of extraction equipment being used. Covering your skin and wearing gloves will prevent exposure to particulates.

An effective laser safety program relies on the implementation of each of the three areas of controls and basic common sense. As with other conservation processes, a risk assessment should be carried out prior to performing work to identify all risks associated with the process and enable the implementation of controls that will reduce risk to an acceptable level.

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Laser Safety Resource

Laser safety is covered in the European standard EN 60825-14 (2004): "Safety of Laser Products, Part 14. A User's Guide;" and the ANSI Z136 series of laser safety standards in North America.