Medical laser safety

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Abstract:

This is a review paper about the most important laser safety procedures, it aims to implement the skills and safety awareness of lasers operation in teaching laboratories and clinical application for students and early careers who could be involved in laser operation and usage. This awareness is of great importance for individual who will be involved in dealing with lasers, as the knowledge and consistent application of laser safety procedures will guarantee a safe working environment of laser.

Keywords: Laser safety, Medical laser

Introduction:

A laser is a device that emits electromagnetic radiation via a process of optical amplification based on the stimulated emission of photons. Laser radiation is characterized by an extremely high degree of coherence, monochromaticity, brightness, and directionality. The wavelength of laser light is extremely pure when compared to other sources of light and all of the photons that make up the laser beam have a fixed phase relationship with respect to one another. Because its properties, laser have made possible a countless number of scientific, commercial, industrial, and medical applications [1,2]. When laser beam directed, reflected, or focused upon an object, laser light will be partially absorbed, raising the temperature of the surface and/or the interior of the object, potentially causing an alteration or deformation of the material. These properties which have been applied to laser surgery and materials processing can also cause tissue damage. Damage can result from both thermal and photochemical effects [3,4]. In addition to the direct hazards to the eye and skin from the laser beam itself, the non-beam hazards, in some cases, can be life threatening, e.g. electrocution, fire, and asphyxiation [4]. So it is of great importance to be familiar with the possible hazards of different class of lasers, and the most important the safety procedures for students and early careers who could be involved in laser operation and usage, to provide a safe working environment.

Laser in Medicine:

Laser based instruments are widely used in medical applications. They are used in treatment of cancer, removal of tumors of vocal cords, brain surgery, plastic surgery, gynecology and oncology. Laser therapy causes less bleeding and damage to normal tissue than standard surgical tools do, and there is a lower risk of infection [5,6]. Surgical removal of tissue with a laser is a physical process similar to industrial laser drilling. Carbon-dioxide lasers operating at 10.6 micrometers can burn away tissue as the infrared beams are strongly absorbed by the water that makes up the bulk of living cells. A laser beam cauterizes the cuts, stopping bleeding in blood-rich tissues such as gums. Similarly, laser wavelengths near one micrometer (Neodymium-YAG Laser) can penetrate the eye, welding a detached retina back into place, or cutting internal membranes that often grow cloudy after cataract surgery. Less-intense laser pulses can destroy abnormal blood vessels that spread across the retina in patients suffering from diabetes, delaying the blindness often associated with the disease. Ophthalmologists surgically correct visual defects by removing tissue from the cornea, reshaping the transparent outer layer of the eye with intense ultraviolet pulses from Excimer Lasers [6,7,8]. So getting the right amount of the right wavelength of laser energy to the right tissue to damage or destroy only that tissue, and nothing else.

Laser Hazards:

However, if laser beam hit untargeted tissue, it can be hazardous and can cause damage to that tissue, particularly for the eye (sometimes also for the skin), mostly because they can have high optical intensities

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even after propagation over relatively long distances. Even when the intensity at the entrance of the eye is moderate, laser radiation can be focused by the eye's lens to a small spot on the retina, where it can cause serious permanent damage within fractions of a second – even when the power level is only of the order of a few milliwatts. Laser damage of the eye is not always immediately noticed: it is possible e.g. to burn peripheral regions of the retina, causing blind spots which may be noticed only years later (Fig.1) [3,7].

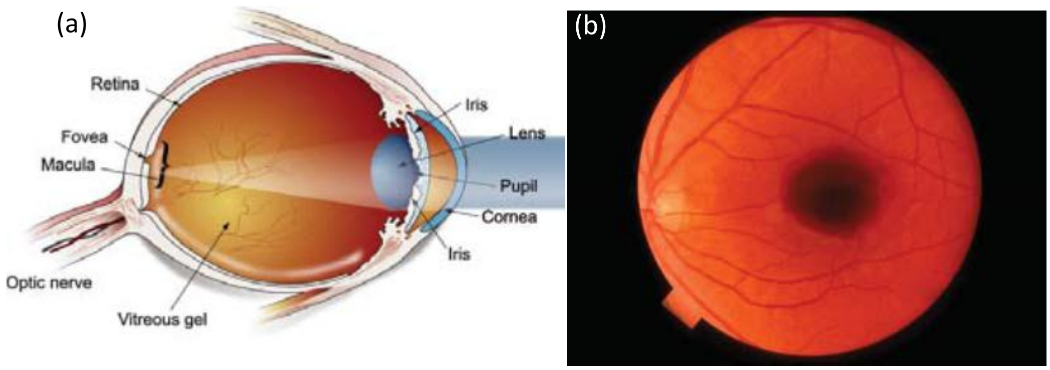

Fig. 1. (a) Simple schematic of the eye, (b) Retinal Injury [9].

On the other hand, lasers can harm the skin via photochemical or thermal burns. Depending on the wavelength, the beam may penetrate both the epidermis and the dermis. The epidermis is the outermost living layer of skin. Far and Mid-ultraviolet (the actinic UV) are absorbed by the epidermis. A sunburn (reddening and blistering) may result from short-term exposure to the beam. UV exposure is also associated with an increased risk of developing skin cancer and premature aging (wrinkles, etc) of the skin. Laser effects on tissue depend on the power density of the incident beam, absorption of tissues at the incident wavelength (Fig. 2), time beam is held on tissue, and the effects of blood circulation and heat conduction in the affected area [10].

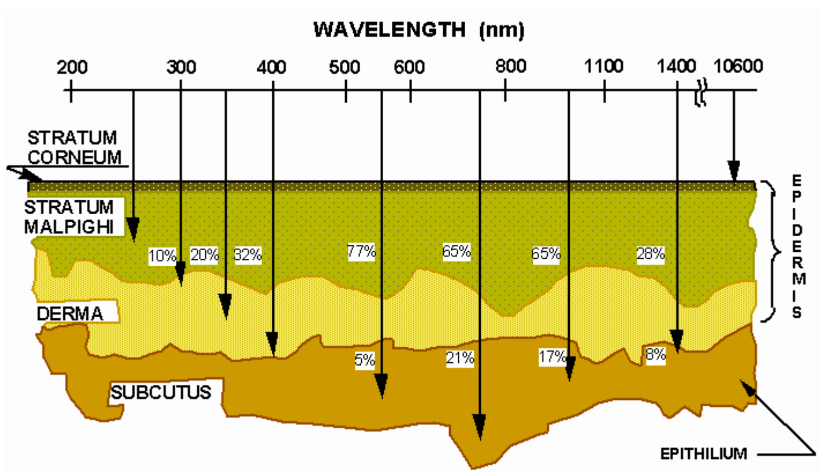

Fig. 2. Different wavelengths of light penetrate the skin [10].

The correct control of laser parameters mentioned above will lead to a successful treatment of the target area, otherwise will lead to skin damage if it uncalculated well. An example is a current work of our group on project related skin temperature evaluation during laser therapy, using long-pulse Nd-YAG laser for portwine stain treatment (Fig. 3). A monitoring of skin temperature during therapy was studied to prevent the raise of skin temperature during therapy to unwanted level which can cause skin damage, a cooling system was used on skin to reduce the thermal and pain effect during therapy. Skin temperature without and with cooling system are shown in Fig. 4. (a) and (b) respectively.

Fig. 3. Lesion laser therapy.

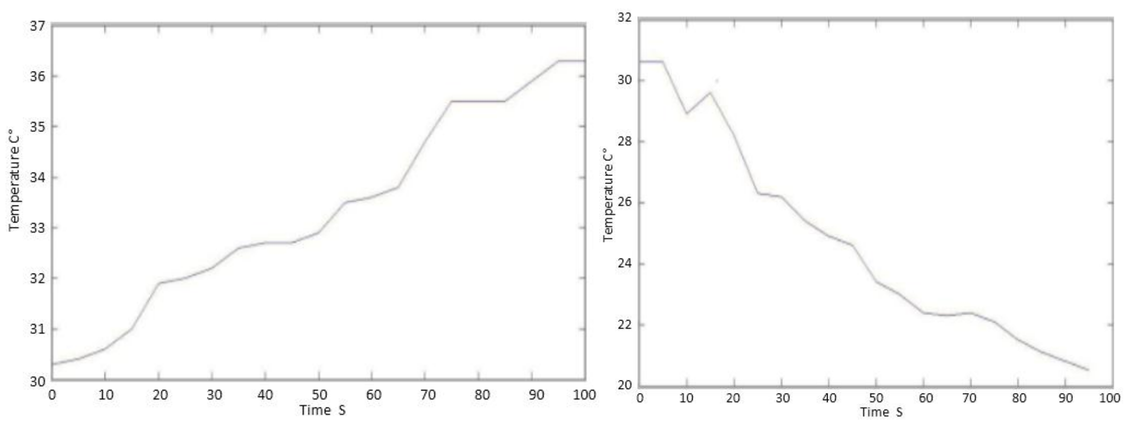

Fig. 4. Skin temperature during laser therapy, (a) without cooling, (b) with air cooling.

In addition to the direct hazards to the eye and skin from the laser beam itself, it is also important to address other hazards associated with the use of lasers. These non-beam hazards, in some cases, can be life threatening, e.g. electrocution, fire, and asphyxiation [4].

Laser Classifications:

Because of the wide ranges possible for the wavelength, energy content and pulse characteristics of laser beams, the hazards arising from their use varies widely. It is impossible to regard lasers as a single group to which common safety limits can apply. A system of laser classification is used to indicate the level of laser beam hazard and maximum Accessible Emission Levels (AELs) have been determined for each class of laser[11]. The previous classification system, which was based on five classes (1, 2, 3A, 3B & 4), has been replaced with a new system of seven classes (1, 1M, 2, 2M, 3R, 3B & 4) and these are described in Table (1). And their level of hazards as shown in Fig. 5.

Table 1. Classification of lasers [11,12].

Laser Class	Description
Class 1	Incapable of causing injury during normal operation.
Class 1M	Incapable of causing injury during normal operation unless collecting optics are used.
Class 2	Visible lasers incapable of causing injury in 0.25 s.
Class 2M	Visible lasers incapable of causing injury in 0.25 s unless collecting optics are used.
Class 3R	Marginally unsafe for intrabeam viewing; up to 5 times the class 2 limit for visible lasers or 5 times the class 1 limit for invisible lasers.
Class 3B	Eye hazard for intrabeam viewing, usually not an eye hazard for diffuse viewing.
Class 4	Eye and skin hazard for both direct and scattered exposure.

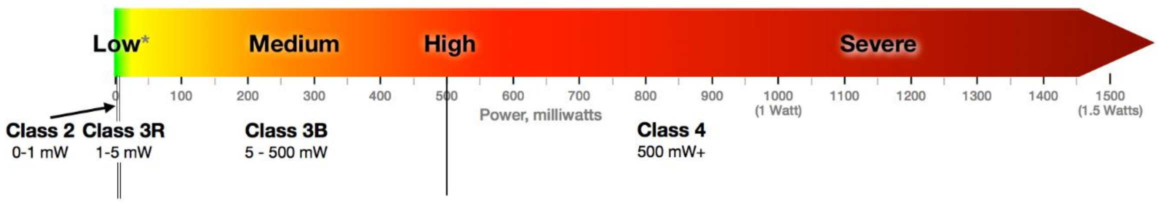

Fig. 5. Laser classes hazard level [13].

Safety Procedures:

So from what mentioned previously, it is essential to design, use and implement a safe laser working environment to minimize the risk of laser accidents, especially environment involving students, patients and early careers (i.e. teaching laboratories and clinical application). There are two principle international laser safety standards:

- International Electrotechnical Commission (IEC) [14].
- American National Standards Institute (ANSI) Z136 [15].

Both standards share a common classification system for lasers based on their power output, wavelength and pulse duration. They are designed to provide a safe laser working environment and provide measures control including administrative, engineering and procedural controls (which especially should be applied for class 3B and class 4 lasers) and can be summarized as follows [4,16,17]:

•Lasers should be operated by authorized person only.
•Access to the laser operation area for visitors to be limited and provisioned.
•Any potentially hazardous beam to be terminated in a beam stop of an appropriate material.
•Warning sign to be posted at the entrance. Laser area must be posted with the appropriate sign(s). These labels how the classification of the laser and identify the aperture(s) when the laser beam is Emitted (Fig. 6. shows different examples of laser warning signs).
•Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewelry such as rings or watches while working near the beam path.
•Laser safety glasses must be used. Protective eyewear in the form of appropriately filtering optics can protect the eyes from the reflected or scattered laser light with a hazardous beam power, as well as from direct exposure to a laser beam. Eyewear must be selected for the specific type of laser, to block or attenuate in the appropriate wavelength range (Fig. 7. Shows example of laser protective eyewear).
•Skin Protection. When there is a possibility of exposure to laser radiation greater than the MPE for skin, individual users are required to use protective gloves, clothing, and shields.

•Wherever possible the beam path must be enclosed. Use fire resistant materials for enclosing Class 4 laser beam path.
•All windows and doors in the laser room to be made opaque.
•The laser system must be disabled (e.g., removal of the key) after use to prevent unauthorized use.
•A screen or curtain must be used to prevent exposure to the laser beam at the entrance of the laser room.
•Users must never view the beam at the level of the horizontal plane where they are passing.
•Watches and jewelry must not be used in the laboratory.
•Alignment of beams and optical components must be performed at a reduced beam power whenever possible.
•Fire extinguishers must be at an easily accessible location in labs using Class 4 lasers. Keep flammable materials away from open beams.
Secure optical components to the table to prevent stray reflections from misaligned optics.
•Interlocks and automatic shutdown**.** Interlocks are circuits that stop the laser beam if some condition is not met, such as if the laser casing or a room door is open. Class 3B and 4 lasers typically provide a connection for an external interlock circuit.
•Laser safety officer(LSO). The LSO is responsible for ensuring that safety regulations are followed by all other workers in the organization.

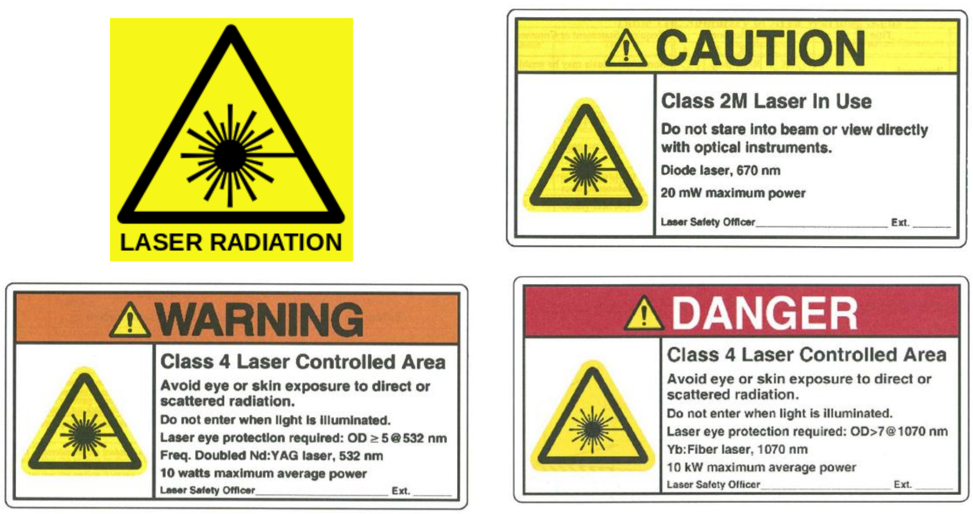

Fig. 6. Different examples of laser warning signs [17].

Fig. 7. Laser protective eyewear.

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