Laser(hygiene)

Laser is an optical device that emits coherent radiation, i.e. radiation that has the same wavelength, phase and direction of propagation. The name "LASER" is an abbreviation of the English designation **L'**ight **A'**mplification by **S'**timulated **E**mission of **R'**adiation.

Laser

Properties of laser radiation :

- monochromaticity (identical wavelength)
- possibility to achieve high intensity
- low divergence of the radiation beam (identical direction of propagation)

The principle of the laser is based on the phenomenon of **forced emission of radiation**. It has been known before that excited atoms or molecules can emit radiation not only when the atom *spontaneously* transitions to a lower energy level, but also *forced* by external electromagnetic radiation, whose frequency is the same as the frequency of the radiation corresponding to the transition of an electron from the excited to the fundamental energy level.

If a substance contains particles in excited states, then irradiation of the substance by a photony with energy equal to the difference in energy levels between the excited and ground states will cause the excited particles to transition to a lower energy state, associated with the emission of radiation with the same **wavelength'**, **phase'** and **direction of propagation** as the radiation that caused the emission. In the ground state, atoms have the lowest energy. Due to external radiation (pumping energy into the laser medium), the atoms of the laser medium can enter excited states from which they can transition to the ground state:

1. **spontaneously'** - independent, "random" transitions produce incoherent radiation, or
2. **Forced'** - due to external electromagnetic radiation there can be forced emission of coherent radiation with the same parameters as the external trigger radiation.

The first optical quantum generator was built in 1960. The active substance was a *synthetic ruby crystal*. Nowadays, lasers based on

- gaseous
- liquid
- fixed phase
- semiconductor based

emitting monochromatic radiation covering the wavelength range of *infrared*, *visible* and *ultraviolet* radiation.

Lasers emitting radiation at multiple wavelengths are called multimodal. The laser can emit radiation continuously, in continuous mode or in pulsed mode, i.e. in flashes lasting from tenths of seconds to fractions of a nanosecond. Lasers that emit repetitive pulses more than once per second are called *high repetition rate lasers*.

Use of lasers

- Lasers have found their application in biology, medicine, in the possibility of realizing controlled thermonuclear reactions, to accelerate particles and in many other fields (aesthetic dermatology, surgery, etc.).
- They are part of many laboratory instruments, measuring and surveying equipment in construction and surveying, used to create special optical effects, etc.
- In engineering, used for welding metal parts, cutting material, etc.

Effects of laser radiation

The effect of the laser on tissues depends on the wavelength of the emitted light. Radiation in the visible region of the spectrum does not penetrate deep into the tissues, therefore mainly the eyes and skin are damaged. A thermal effect on the skin occurs when the temperature rise at the site of impact is faster than 10-25 °C/min. The depth of thermal damage depends on the wavelength:

- longwave infrared radiation is absorbed by water and does not penetrate below the surface,
- shortwave radiation can penetrate to a depth of about 5 mm and affect blood vessels deep in the skin and subcutaneous tissue.

Very short exposures, induced by high energy flashes, cause such rapid evaporation of water in the tissue that microexplosion occurs, causing mechanical changes in the tissue without extensive thermal devastation of the surrounding tissue. This phenomenon is used in plastic surgery.

When the laser beam hits the tissue, the following basic phenomena occur:

- reflection;
- dispersion;
- absorption;
- transmit.

Irradiation of tissue with laser beams has the following **effects'**:

- **photobiochemical effects'**

A: Phenomena such as photostimulation, photoresonance or photoactivation occur by photobiochemical effects. Also included here is photochemotherapy, which finds application in e.g. photodynamic therapy.

- **photothermal effects'**

A: Photothermal effects cause a local increase in tissue temperature. This technique is used in **coagulation** (e.g. blood clotting, protein denaturation) and further temperature increase leads to **vaporization** (water evaporation) to carbonization of the tissue section.

- **photoionizing effects'**

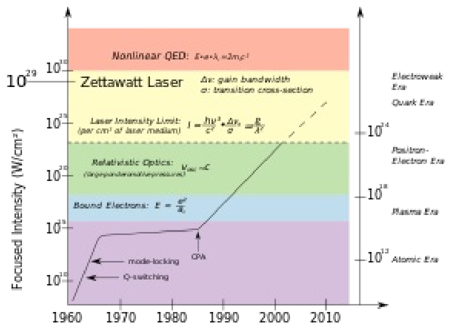
  Irradiation with a radiation intensity greater than 107 W.cm^{-2} will cause photoionizing effects. The light energy is converted into kinetic energy of electrons, which easily breaks the bonds between atoms. This process is so fast that the heat generated at the irradiated site is not transferred to the surrounding tissues. Instead, the long organic chains are broken into small and light particles. This process is referred to as **photoablation** or **microexplosion**. Photoablation is made possible by short waves of an excimer laser.

Effects of laser radiation on the eye

The effect of laser radiation on the eye depends on its **wavelength**, as this determines in which part of the eye the radiation is absorbed. The cornea and the fluid in the anterior chamber absorb almost all infrared radiation with a wavelength greater than 1400 nm, which can lead to **heating of the lens** and **cornea** and cause **thermal damage** to them. Radiation in the wavelength range of visible light and short-wave infrared radiation, i.e. 400-1400 nm, passes through the optical system of the eye and can therefore damage the retina. The optical system of the eye concentrates the beam of radiation and thus increases the energy density of the radiation so that it is up to about 100,000 times higher on the retina than on the surface of the eye. Exposure of the eye to sufficiently intense radiation results in *thermal damage* to the retina with denaturation of proteins and inactivation of enzymes. When the retina is hit by a flash with high energy density, ultrasound oscillations and displacements of the surrounding tissue are also generated on the retina. The retina heals with a *scar* at the site of the hit, the location of which determines the severity of the visual disturbance. The most severe damage is yellow spots. Retinal damage from laser radiation is rare.

Division of lasers

The basic parameter for dividing lasers into safety classes is the Accessible Emission Limit (AEL), which expresses the maximum level of emission allowed in a given class. The Maximum Permissible Exposure (MPE), which indicates the level of laser radiation to which persons can normally be exposed without experiencing adverse effects from the exposure, is decisive for the classification of lasers in terms of operator safety. MPE levels are the maximum radiation levels at which the eyes or skin can be exposed without immediate or long term resultant damage. MPE levels are dependent on the wavelength, the pulse duration or time of exposure, the type of tissue irradiated and, for wavelengths of 400 nm to 1400 nm, the size of the image on the retina. The lasers are divided into the following safety classes (simplified description of the classes without performance):



History of laser development

1. *Class 1 lasers* - have such low power that no special precautions are needed for their use;
2. *Class 2 lasers* - emit only low-power visible radiation, eye damage could occur only when looking into the beam for a prolonged period of time;
3. *Class 3 lasers* - divided into 2 groups:
   1. **Class 3A'** - can cause retinal damage if the eye is accidentally hit by a beam of radiation that enters the eye through an optical instrument such as a telescope;
   2. **Class 3B'** - emit radiation that can cause damage to the eye if accidentally hit by a direct or specularly reflected beam;
4. *Class 4 lasers* - radiation can cause damage to the eye or skin even with diffuse reflected beams.

Types of lasers used in medical practice

- **CO_2 laser'** - radiation is well absorbed by the tissue. Penetration is limited to a depth of approximately 0.1 mm. The use of this laser also results in photocoagulation of small hair cells, which limits bleeding.
- **Neodymium laser'** - usually used to stop bleeding or to close the digestive system.
- **Argon laser'** - the main application is in ophthalmology. Its blue light is absorbed mainly by the blood, so it is used in photocoagulation of small blood vessels and in retinal detachment.
- **Dye lasers'** - the beam causes fragmentation of e.g. gallbladder and kidney stones. Thanks to the tunability of their wavelength, they are also used in diagnostics, where they induce luminescence of the molecule under investigation.
- **Excimer lasers'** - emit radiation in the UV region and exhibit an unusually clean cut. In addition to clearing clogged blood vessels, they are also used in ophthalmology to correct myopia and astigmatism.

Measures to protect health from laser radiation

Each laser must be marked with the class and its corresponding warning label. The measures also include in particular requirements for:

- procedures for modifying lasers that may alter their radiation parameters, requirements and protection against improper handling and launching by unauthorized persons,
- measures to prevent people from entering the bundle path, etc.

These measures are applied differentially by class. Operating instructions shall be drawn up for each workplace using lasers of class 2 and above and these shall be discussed with the health service authority. When handling mainly mobile lasers, such as those used in various fields of medicine, accidental eye contact cannot be completely ruled out. It is therefore necessary to fit protective goggles both for the personnel handling them and for those in the vicinity of the radiation. Protective goggles are designed to selectively attenuate the wavelength of radiation emitted by the laser.

Links

Related articles

- Laser (biophysics)
- Laser in dental surgery
- Use of lasers in medicine

References used

- BENEŠ, Jiří. *Základy lékařské biofyziky.* 1. edition. Praha : Univerzita Karlova, 2006. 196 pp. pp. 128-129. ISBN 80-246-1009-4.