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IMPORTANCE OF LASERS IN MEDICINE

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Abstract

This article discusses in detail the importance of lasers in medicine, including their role in surgery, dermatology, cosmetology, dentistry, and diagnostics. It also examines the methods of using lasers in ophthalmology and in the crushing of kidney stones.

Keywords

Lasers, medicine, coagulation, surgery, ophthalmology, dermatology, cosmetology, dentistry, diagnostics, kidney stones.

Principle of Laser Operation

Light has been used to treat various diseases since ancient times. Ancient Greeks and Romans used the Sun as a form of medicine. The list of diseases that could be treated with light was quite extensive.

The development of phototherapy dates back to the 19th century. The invention of electric lamps contributed to this progress. At the end of this century, attempts were made to treat smallpox and measles using red light. “Light baths” were also widely used in the treatment of various mental illnesses.

In the 1960s, the first laser devices began to be used. Today, laser technologies are applied in the diagnosis and treatment of almost all diseases.

The operation of lasers is based on the phenomenon of stimulated emission. This phenomenon was introduced into science as a postulate by A. Einstein in 1916.

Now let us briefly consider laser radiation.

Lasers are quantum generators of radiation operating in the optical range (QGR). Let us consider their operating principle.

It is known that as a result of the interaction of radiation with matter, atoms of a substance can absorb a photon and move to an excited state with higher internal energy.

This state is not stable. Usually, the lifetime of atoms in this state is very short, that is about

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10^{-8} seconds. At some moment, atoms in the excited state spontaneously emit photons and transition to a state with lower energy.

Such radiation is called spontaneous emission. Spontaneous emission has a random character. Therefore, this radiation is isotropic (does not have any main direction), not coherent (quanta emitted by different atoms have different phases), and not monochromatic (consists of a set of different frequencies). Such radiation is produced, for example, by incandescent and gas-discharge lamps.

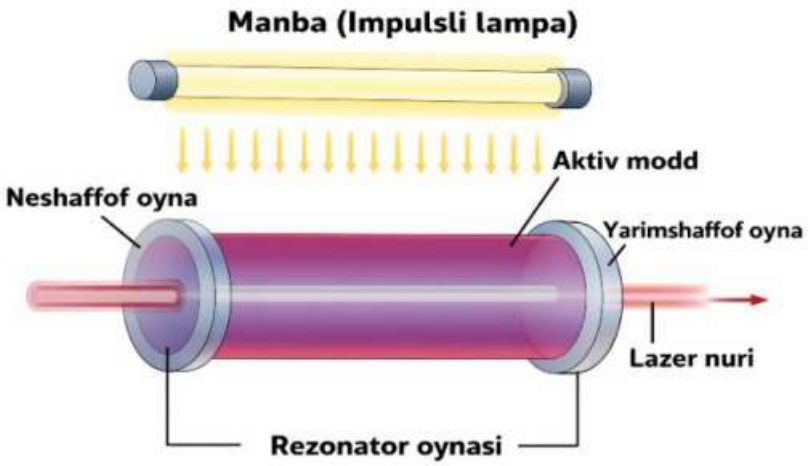

Figure 1. Principle diagram of a laser

1 – active medium
2 – fully reflecting mirror
3 – semi-transparent mirror
4 – pumping
5 – generated radiation

The transition of atoms from excited states to lower excited states may also occur under the influence of photons falling on them. However, for this to occur, the energy of the photon must be equal to the transition energy.

In this case, two photons are produced simultaneously: the incident photon and the photon formed as a result of the atom transitioning from one state to another. In this situation, the incident photon induces (forces) the atom to transition from the excited state to a lower excited state. Therefore, such radiation is called induced or stimulated radiation. The stimulated emission of an excited atom occurs not only under the influence of an external photon, but also under the influence of a photon of induced radiation.

When the number of excited atoms becomes sufficient, this phenomenon leads to an avalanche-like increase in radiation.

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Coherence, monochromaticity, and having a definite direction are the main properties of induced radiation. The reason for this is that the frequency, phase, momentum, and polarization of the quantum falling on the excited atom are identical. Stimulated radiation forms the physical basis of the operating principle of lasers.

The probability of stimulated transitions increases as the number of incident quanta and the number of excited atoms increase.

Under natural conditions, the number of particles in the excited state in a substance is smaller than the number in the lower excited state. In order to amplify the radiation produced due to stimulated transitions, the number of atoms in the excited state must be greater than the number in the lower excited state.

Such a relationship between particles is observed in some substances. In these substances, there exist excited states of particles from which the probability of spontaneous transition to a lower excited state or to the ground state is very small.

The lifetime of an atom in such a state is long (up to 10^{-3} sec). The levels corresponding to such energetic states are called metastable levels.

Under the influence of the excitation process, the number of atoms at such levels increases and begins to accumulate. As a result, a state occurs in which the number of atoms at the metastable excited level becomes greater than the number of atoms at the lower excited level. In such a state, substances form the active (working) medium of a laser.

To create an inversion population state, methods such as separating the required particles (separation method), exciting particles using light (optical method), or using electric charge (electric method) are applied.

Let us consider the mechanism of laser radiation.

Gas discharge is produced with the help of electrodes installed outside or inside the discharge tube. During the electric discharge, neon atoms interact with electrons and transition from the ground state with energy E_0 to the metastable state with energy E_2.

When neon atoms transition from the energetic state E_2 to the energetic state E_1, radiation corresponding to the red part of the spectrum is produced.

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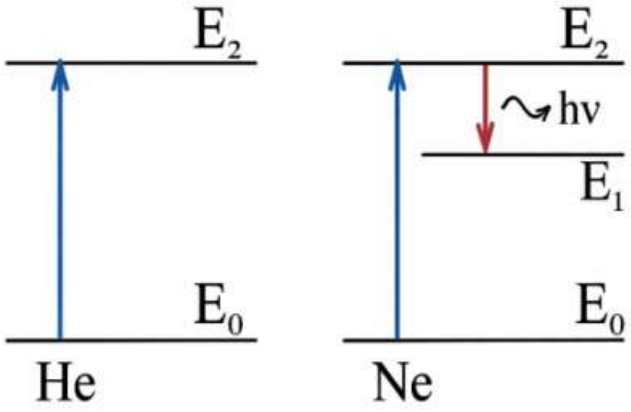

As a result of inelastic interaction, helium atoms transfer their energy to neon atoms, and neon atoms transition to the excited E_2 state. Neon atoms in the E_1 energy state interact with the wall of the tube and transition to the ground state. In this way, the number of neon atoms in this state continuously decreases.

As a result, helium atoms create a stationary population inversion of neon atoms at the E_2 level relative to the E_1 level. Thus, in this laser, neon atoms act as the working substance, while helium atoms serve as auxiliary atoms. Gas lasers belong to continuously operating lasers. Coherence, high monochromaticity, precise directionality, and high power are among the main properties of lasers, which enable their wide application in science and technology.

When laser radiation interacts with matter, it heats the point where it falls and sharply increases the temperature. As a result, changes in the state of matter (melting, evaporation), formation of shock waves, and intensive heat exchange are observed.

These properties, such as the ability to concentrate laser radiation energy into a thin (micro) beam and its selective absorption, make it widely applicable in medicine.

Laser beams are used in surgery to cut tissues without bleeding, because under its influence, the edges of the cut tissue are welded together, preventing capillary bleeding. In oncology, it is used to destroy cancer cells (because laser radiation is strongly absorbed in them).

Laser beams are used in surgery to cut tissues without bleeding, because under its influence, the edges of the cut tissue are welded together, preventing capillary bleeding. In oncology, it is used to destroy cancer cells (because laser radiation is strongly absorbed in them).

In ophthalmology, laser beams are used to "weld" displaced retinal tissue and to create microscopic holes in the sclera to drain intraocular fluid for the treatment of glaucoma.

In dermatology, radiation from gas lasers is used for therapeutic purposes.

Taking into account the characteristics of the effect of laser radiation on biological tissues, it is necessary to prevent the beam from falling on the experimenter during operation (even the beam reflected from an object). Coagulation mainly occurs due to the absorption of laser radiation by blood, causing it to boil and form thrombi. In the coagulation process, hemoglobin or the aqueous component of blood acts as the absorbing target.

Surgical lasers are divided into two large groups: ablative and non-ablative lasers. Ablative lasers perform functions similar to a scalpel. Non-ablative lasers work on a different principle: after acting on an object, for example, a wart, papilloma, or hemangioma, it remains in place, but after some time, certain biological processes occur in them and they fall off. In surgery, mainly continuously operating CO_2 lasers are used. Their effect is based on the thermal effect. The advantages of laser surgery include the absence of bleeding, sterility, local effect, and the absence of scarring. In oncology, laser radiation affects tumor cells. This effect is also based on the thermal effect.

Today, the method of photodynamic therapy is also developing. Its principle is as follows: a special substance — a photosensitizer — is introduced into the patient's body. This substance accumulates around the tumor. After the tumor is irradiated with a special laser, several types of photochemical reactions occur with the release of oxygen, and tumor cells die.

In ophthalmology, lasers are used both for treatment and diagnostic purposes. With the help of lasers, it is possible to connect the retina of the eye and various small vessels. In microsurgery, argon lasers emitting in the blue-green region of the spectrum are used in the treatment of glaucoma. Excimer lasers are successfully used for vision correction. In dermatology, many severe chronic diseases are treated with the help of laser radiation, and tattoos are removed. When irradiated with laser light, regenerative processes are activated, and the exchange between cellular elements becomes more active.

The application of lasers in cosmetology is based on their absorption when they fall on an object or substance. In the skin, light is absorbed by special substances — chromophores. Each chromophore absorbs light within a certain wavelength range. For example, for the yellow and green spectrum this is blood hemoglobin, for the red spectrum it is hair melanin, and for the infrared spectrum it is the water inside the cells. During absorption of radiation, the energy of laser

radiation is converted into heat in the part of the skin where the chromophore is present. With sufficient power of the laser beam, this leads to the destruction of the target. Thus, with the help of lasers, it is possible to selectively affect hair roots, pigment spots, and other skin defects. In laser cosmetology, it is necessary to correctly select not only the wavelength but also the energy of lasers and the duration of impulses. In dentistry, laser radiation is considered the most effective physiotherapeutic method in periodontal disease and diseases of the oral mucosa.

The instruments used in laser surgery deliver high-power laser radiation to the required location during operations performed in urology, gynecology, gastroenterology, general surgery, and dermatology.

In diagnostics, lasers are used to detect various tumors, hematomas, and in living organisms

The cornea begins to refract light rays differently, and the image becomes clear. Laser vision correction using the LASIK method

Pain-relieving eye drops are instilled into the patient's eye (general anesthesia or anesthetic injections are not used). After that, the patient's eyes are kept open using a special instrument.

The patient lies looking at a bright point in the device.

Using a special instrument — a microkeratome — a "flap" 130–150 microns thick is created from the upper layers of the cornea and opened. This allows the laser beam to penetrate deeper parts of the cornea.

The laser beam evaporates a part of the cornea, forming a new surface.

The "flap" is placed back in position and is fixed due to collagen, which is the natural substance of the cornea.

Suturing is not required. Restoration of the epithelium at the edges of the "flap" occurs independently.

After completion of laser correction, the cornea is washed with a special solution. Special drops are instilled to prevent inflammation.

The patient can return to work the day after the operation.

Cataract. Cataract is the most common eye disease in elderly people. In youth, the eye lens is transparent and elastic — it can change its shape almost instantly. Due to this, the eye can see both distant and near objects well. In cataract, the eye lens becomes partially or completely cloudy, and only part of the light rays enters the eye. Therefore, vision decreases and the person begins to see unclearly. If treatment is not carried out in time, cataract may lead to blindness.

Femtocataract — treatment of cataract with laser.

The most modern method of cataract treatment is treatment with the LenSx femtosecond laser.

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Application of femtosecond laser

Using optical coherent tomography, all parameters of the eye are measured before the operation.

The femtosecond laser system divides the eye lens into layers. This process is carried out either by dividing into sectors or in a circular manner. Using the laser, an opening is created in the capsule of the eye lens. Due to the properties of femtosecond technologies, the opening becomes ideally smooth. At this stage, the laser action is completed, and the remaining processes are performed using a microsurgical system. The eye lens separated with the help of laser radiation is converted into an emulsion under the influence of ultrasound and removed from the eye. Through a 1. 6 mm opening, an intraocular lens is inserted in a folded form into the capsule where the eye lens was previously located, and it opens independently inside the eye and is securely positioned. To perform operations using the new method, the LenSx surgical femtosecond laser system manufactured by the Alcon (USA) company is used.

This system is equipped with intraoperative optical coherent tomography. This makes it possible to monitor all parameters during the operation. As a result, the operation can be performed accurately and safely.

All parameters are calculated individually by the system for each patient.

The uniqueness of the femtosecond laser lies in the fact that its beam can be focused to a thickness of several microns at any desired depth. In this case, a layer of microbubbles is formed, which can separate tissues at the molecular level without releasing heat and without affecting surrounding tissues.With the help of this method:

It is possible to completely eliminate cataract.

The postoperative recovery period is minimal.

Vision is restored very quickly after the operation.

Thus, observations and experiments show that laser technology in medicine is continuously developing. Every year, new scientific works, technical improvements, and clinical studies expand the role of lasers in medicine; photogenetic therapy, long-wavelength lasers, portable equipment, and personalized treatment methods are developing rapidly over a wide range. Therefore, lasers can be considered one of the ways of using future technologies in medicine.

Lasers are starting a new era in medicine, providing especially precise and minimally invasive methods for diagnosis and treatment. In the future, technology will continue to develop.

Doctors and the scientific community continue to monitor the development of laser technology, and new techniques and methods further improve patient treatment. These developments create great opportunities.

Science expands the possibilities of laser technology, accelerates interventions, and increases safety for patients. Innovations guarantee important changes in medicine. Advantages of using lasers in healthcare include less bleeding, shorter recovery periods, and safer treatment for patients.

Lasers are widely used in medicine, opening new opportunities in this field, accelerating treatment processes, and making their effects more precise. This technology plays an important role in solving medical problems.

Laser application techniques are constantly developing, which creates opportunities to make diagnostics and treatments in medicine more accurate, safe, and convenient.

Types of lasers in medicine

Lasers are widely used in medicine. They are important instruments for treating various diseases, restoring injuries, and performing diagnostics. They provide fast and effective results.

There are many types of lasers, each having its own specific operating principle. Their use is common in surgery and cosmetology.Medical lasers continue to develop, and new technologies are being introduced. These approaches make treatment less painful for patients and speed up the treatment process, providing special advantages.

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