

# Usage of lasers in medicine

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In medicine, the laser beam is used as part of so-called phototherapy for many procedures, including, for example, the correction of vision defects or the smoothing of microscars. The first such interventions were carried out in the 1970s, but the wider scope of the laser in medicine was not heralded until the beginning of the third millennium. 

A brief description of the principle of laser operation : A laser is a device emitting coherent electromagnetic waves, which is radiation whose rays have the same phase, direction of propagation and wavelength. The name comes from the English abbreviation **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. A photon is an elementary particle mediating electromagnetic interaction. It has some energy. A directed stream of many photons (laser) can transmit large amounts of energy, which can be used in some medical procedures, most often by converting it into thermal energy.

## Fields using laser

The fields of medicine that use lasers for medical procedures include, for example, **neurology** , **surgery** , **plastic surgery** , but also **dermatology** , **urology** , **gynecology** and **dentistry** .

## Classification of lasers used in medicine

Medical laser devices are divided according to performance. The higher the power, the more energy the rays transport. Their practical use therefore depends on their performance. Each medical discipline requires a precise characterization of laser use for its purposes, as a different laser wavelength is suitable for each type of tissue. A longer wavelength penetrates deeper into the tissue, but does not act as strongly. Shorter wavelengths are suitable, for example, for dentistry, longer ones are used in rehabilitation. Furthermore, it will also depend on the absorption of the laser beam by the medium through which it passes, whether it is absorbed by water or hemoglobin. Basic division of lasers according to performance:

1. **Non-invasive** - or therapeutic. Their power does not exceed 500mW.<sup>[1]</sup>
2. **Invasive** - i.e. surgical. The power of these devices is greater than 1W.<sup>[1]</sup>

## Advantages of using a laser

In medicine, the laser has become widespread as a means of treatment methods due to several specific properties.

1. **Sterility** - when using a laser scalpel, tissue does not come into contact with a foreign body that could contain various sources of infection, such as bacteria.
2. **Precision** - the laser scalpel has an effective area significantly narrower than a regular steel scalpel, but it is no less effective. On the contrary, the incision is very thin and only necessarily long, so healing is faster and the whole process is gentler on the body.
3. **Possibility of tissue vaporization**- the tissue can be heated to a very high value with a laser and thus removed from the body.

## Effect of laser contact with tissue

When using a laser in medicine, it is not only the wavelength, the set power and subsequently the energy produced by the device that matters, but also other characteristics of its work, such as the frequency of the individual transmitted impulses and the inherent characteristics of these impulses. Specifically, how long the given impulse will last, what energy it will have and how the energy will be distributed over time during this impulse. Different laser effects can be achieved with this setting. E.g. tissue vaporization versus hemostasis, tryps of concretion into large fragments versus tryps into small particles, or dusting.

- **Photocoagulation:** tissue destruction by incident radiation. The most important application include retinopathy surgery.
- **Vaporize:** removal of tissue by vaporization.
- **Ablative photodecomposition:** absorption of radiation leading to the formation of molecular fragments, which are converted into the gas phase by high temperature (necessary cooling of the tissue before and after the procedure).
- **Photothermal effect:** using this interaction of the laser with the tissue, it is possible to stop the bleeding of some structures, for example peptic ulcers – the effect is widely used in endoscopic interventions.
- **Photochemical interaction:** this is a change in the chemical structure of the tissue after irradiation, which will supply the activation energy for this process.
- **Tearing of tissue:** a procedure that induces a sharp increase in temperature up to 1250 °C in the affected tissue with the laser, and thus an increase in pressure, the result of which is tearing and devastation of the tissue.<sup>[1]</sup>

## Use of laser in surgery

The development of laser technology in recent decades has enabled the creation of a new field of medicine– laser surgery. From a physical point of view, the surgical laser works either on the principle of evaporating liquids from soft tissues or on breaking the molecular bonds of substances contained in the tissue.

### Overview of used lasers

- **CO<sub>2</sub> laser** –This type of laser is not very penetrating and penetrates only about 0.1 mm deep into the tissue. However, this can be used in a number of interventions, such as onychocryptosis (ingrown nails), onychogryposis (claw-like curvature of the nails) or onychomycosis (fungal disease of the nail beds).
- **Nd YAG laser (neodymium)** – Thanks to its wavelength of 1064 nm, the laser reaches the invisible infrared part of the spectrum. The laser source is neodymium in a yttrium-aluminum-garnet crystal, and excitation is provided by a krypton lamp. For practical use, its emission must be combined with a ruby guide beam. This laser is much more penetrating than the CO<sub>2</sub> laser. It is one of the most widely used lasers in gastroenterological operations (used, for example, to stop bleeding). It is also used to remove cataracts or to reduce intraocular pressure
- **Nd YAG laser with KTP crystal** (referred to more often as KTP laser or GreenLight laser ) – the radiation source is also a neodymium laser, but the beam passes through a potassium-titanyl-phosphate crystal (KTiOPO<sub>4</sub>), which colors it green. The color spectrum changes due to the reduction of the wavelength by half, i.e. from 1064 nm to 532 nm. And we actually see the beam. It is not absorbed by water, but by red elements, i.e. hemoglobin in red blood cells. Which limits its penetration to 0.8 mm. Owing to the small depth of action, the formation of edema in the tissue is limited, as well as the detachment of necrotic tissue is minimal. <sup>[2]</sup>
- **Argon laser** – effective, for example, in the treatment of diabetic retinopathy. Today, the procedure is also performed on an outpatient basis.
- **Dye laser** – targeted beam causes gallstones to break up.
- **Excimer laser** –used to open blood vessels and, due to its accuracy, also in the treatment of myopia.



Laser scalpel Sharplan 40C

## Use of laser in dermatology

Especially in dermatology, the laser is widely used, especially for the treatment of poorly healing wounds, scars, bedsores, cold sores, vascular lesions, pigment spots, smoothing of the skin surface, treatment of acne, removal of unwanted hair and biostimulation of cells. In contrast to surgery, a low-power laser is much more often used in dermatology, which achieves biostimulation of tissue cells and thus also quick, effective and much more comfortable treatment of congenital malformations, which previously had only very limited treatment options.

The principle of operation of the laser in hair and acne removal is thermodestruction. In the first case, the laser is aimed specifically at cells containing melanin, and the procedure must be repeated several times in order to destroy even cells that were previously in an early stage of development. In the treatment of acne, so-called blue light is used, which directly destroys the bacteria causing this inflammatory skin disease.

With regard to precisely defined contraindications, there is no risk of side effects of this treatment with the correct use of the laser in dermatology. When applying biostimulating radiation, however, it is necessary to take care to protect the eyes with special glasses.



Permanent hair removal on the calf using a laser

## Use of laser in ophthalmology

Laser techniques were first used in ophthalmology. Currently, a very advanced device is the so-called **femtosecond laser** (its radiation lasts in the order of femtoseconds - fs). This pulsed laser is able to create raster shapes in the eye tissue by the summation of its plasma microbursts. They are used to correct some visual defects and assist in cataract surgery.



VisuMax femtosecond laser

- **Argon laser** - formerly widely used, now obsolete for eye use.
- **The KTP laser or GreenLight laser** is a Nd: YAG laser containing a KTP crystal that adjusts its wavelength to 532 nm - widely used for thermocoagulation eye treatment (complications of diabetes, glaucoma)..
- **Diode lasers** - used to treat some types of age-related macular degeneration (photodynamic therapy) and thermal treatment (heating, burning) of glaucoma and some retinal diseases.
- **Nd-YAG laser creating a plasma spark** - a plasma spark (microburst) is mainly used to create holes in the intraocular tissues without having to open the eye or to break some intraocular structures. It is used to treat, for example, secondary cataracts (can occur after cataract surgery) or eyes with a tendency to develop glaucoma.
- **Excimer lasers** - correction of vision defects, i.e. myopia, hypermetropia nebo astigmatism. This type of laser offers the advantage of high accuracy of the vaporized surface. The phenomenon is referred to as APD - ablative photodecomposition (see above). In this way, the excimer laser reshapes the corneal tissue in such a way that the original vision defect is minimized.

## Use of laser in urology

Nowadays, the laser is widely used in the surgical treatment of diseases, most often in the treatment of benign prostatic hyperplasia nebo urolithiasis. Laser procedures are an alternative solution to more invasive methods of treatment and have many advantages, both perioperative and postoperative. E.g. they shorten the time of hospitalization and allow a shorter time of catheterization of the bladder. It brings more stable results and fewer reoperations.

- **The Nd: YAG laser** with a wavelength of 1064 nm was the first laser used in urology, but nowadays it is not often used in practice. The beam penetrates the tissue to a depth of 4 to 18 mm. At temperatures of 60 to 100°C, protein denaturation occurs and coagulation necrosis forms in the tissue. If the temperature exceeds 100°C, water and hydrocarbons evaporate, and a cavity is created in the tissues due to this thermoablation. Therefore, it is used for deobstructive transurethral operations of the prostate (benign prostatic hyperplasia or prostate cancer), as well as laser ablation of tumors and dissection of strictures of the urinary tract, i.e. cutting narrowed places..<sup>[3]</sup>
- **The KTP laser or GreenLight laser** with a wavelength of 532 nm is used for PVP - Photo-Selective Vaporisation of the Prostate. This is a minimally invasive procedure performed endoscopically. It involves thermal ablation of benign prostatic hyperplasia and vaporization of blood-filled tissues. The advantages of this method are, for example, minimal bleeding during the procedure, a short period of postoperative catheterization of the bladder, rapid postoperative rehabilitation to normal life and a lower probability of postoperative erectile dysfunction. It is an alternative method to TURP, tj. transurethral resection of the prostate. <sup>[3]</sup>
- **Holmium: YAG laser** is one of the most used lasers in urology. It is a pulsed laser with a wavelength of 2140 nm using rare holmium in a YAG crystal. The beam is excited via a xenon lamp. Its penetration is very small, around 0.4 mm. This causes a safe surface vaporization of the tissue without deep coagulation necrosis. It is used for:
  1. **HoLEP (Holmium Laser Enucleation of the Prostate)** , i.e. surgical endoscopic method of treating benign prostatic hyperplasia. This method brings many advantages – less risk of perioperative bleeding, more secure hemostasis, shorter time of postoperative urinary catheter insertion, minimal risk of erectile dysfunction , and it can be performed even in more at-risk patients with less risk than with other methods. Furthermore, unlike other endoscopic methods for the treatment of benign prostatic hyperplasia, it is also possible to treat patients with a large prostate volume. For them, an alternative method to both TURP i TVPE, tj. transvesical prostatectomy.
  2. **Disintegration of urinary tract stones** , for which the Holmium: YAG laser is most commonly used. These are endoscopic surgeries of the upper and lower urinary tract. Specifically, e.g. stones of the calicopelvic system of the kidney during flexible ureterorenoscopy. In which the advantage is the flexibility of the laser fiber and it can therefore be used in flexible devices. It is used as an alternative method of lithotripsy in PEK, i.e. percutaneous stone extraction. Furthermore, ureteral stone trypsis is the preferred method during URS, i.e. ureterorenoscopy. If there is a calculus in the bladder, cystolithotripsy is used, during which the calculus is disintegrated into small fragments or into much smaller fragments, then it is called dusting. Based on the size of the formed particles, they are either removed instrumentally or leave spontaneously through the urinary tract as debris from a stone.
  3. **Evaporation of the tissue** , which is used, for example, in the alternative removal of urothelial tumors of the ureter and calicopelvic system of the kidney, where it is not possible to perform a radical operation or to cross the stricture of the ureter or the transition of the renal pelvis into the ureter..<sup>[3]</sup>
- **Thulium laser** - its beam has a wavelength of 2000 nm and is absorbed by water twice as much as the

Holmium laser. It is used in ThuLEP, i.e. Thulium laser enucleation of the prostate<sup>[3]</sup>

- **The LBO laser** (Lithium triborate laser) is based on the KTP laser and its wavelength is the same, namely 532 nm. However, they differ in energy transfer, which is faster and more efficient. The tissue penetrates to a depth of 3 mm. A significant shortcoming is its low hemostatic effects compared to the KTP laser.<sup>[3]</sup>

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## Use of laser in gynecology

The laser is most often used in gynecology to speed up wound healing and scar treatment, once again to biostimulate tissues and also to eliminate stretch marks. Every mucous membrane is more sensitive to laser action than, for example, the skin, which is why radiation with a longer wavelength is chosen.

## Use of laser in rheumatology

Mainly due to its anti-inflammatory effect, the laser is used in rheumatology in the treatment of arthrosis and other diseases. This treatment is always combined with medication.

## Use of laser in dentistry

A strong laser is now being used instead of dental drills, the advantage is again less pain after the procedure. However, the laser is more widely used in dentistry in the treatment of inflammatory diseases, periodontitis, increasing the resistance of enamel, treating tooth hypersensitivity and against tooth demineralization.<sup>[4]</sup>

## Links

### Related Articles

- Laser
- Laser (biophysics)
- Ophthalmology
- Refractive defects

### External links

- Excimér laser na [www.videni.cz](http://www.videni.cz) (<http://www.videni.cz/operace-oci/clanky/38-excimer-laser%7C>)
- About laser medicine at [www.cpzp.cz](https://www.cpzp.cz) (<https://www.cpzp.cz/clanek/1605-0-Laserova-medicina.html>)
- Laser and its different types <https://cs.wikipedia.org/wiki/Laser>

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