

5.8 ONCOLOGY

It is branch of medicine that studies cancer tumours and seeks to understand their development, diagnosis, treatment and prevention. Lasers can be used in 2 ways to treat cancer.

To shrink or destroy a tumor with heat. To activate a chemical – known as a photo sensitizing agent – that kills only the cancer cells. (This is called photodynamic therapy or PDT.) Though lasers can be used alone, they are most often used with other cancer treatments, such as chemotherapy or radiation.

Lasers are also being studied for treating or preventing side effects of common cancer treatments. For instance, some studies are looking at how low-level laser therapy (LLLT) might be used to prevent or treat severe mouth sores caused by chemotherapy, and how they may be used to treat the swelling (lymphedema) that can result from breast surgery. Shrinking or destroying tumors directly.

The CO₂ and Nd:YAG lasers are used to shrink or destroy tumors. They can be used with thin, flexible tubes called endoscopes that let doctors see inside certain parts of the body, such as the bladder or stomach. The light from some lasers can be sent through an endoscope fitted with fiber optics. This lets doctors see and work in parts of the body that could not be reached otherwise except by major surgery. Using an endoscope also allows very precise aim of the laser beam.

Lasers can be used with low-power microscopes, too. This gives the doctor a larger view of the area being treated. When used with an instrument that allows very fine movement (called a micromanipulator), laser systems can produce a cutting area as small as 200 microns in diameter – that's less than the width of a very fine thread.

Lasers are used to treat many kinds of cancer. In the intestines or large bowel, lasers can be used to remove polyps, small growths that might become cancer. The CO₂ laser can be used to treat pre-cancerous tissue and very early cancers of the cervix, vagina, and vulva.

Lasers are also used to remove tumors blocking the swallowing tube (esophagus) and large intestine (colon). This does not cure the cancer, but it relieves some symptoms, such as trouble swallowing.

The Nd:YAG laser has also been used to remove cancer that has spread to the lungs from other areas. This helps avoid surgery that would require removing large sections of lung. This type of laser cannot cure cancer, but it can improve breathing and other symptoms in many patients.

Cancers of the head, neck, airways, and lungs can be treated (but usually not cured) with lasers. Small tumors on the vocal cords may be treated with lasers instead of radiation in some patients. Tumors blocking the upper airway can be partly removed to make breathing easier. Blockages deeper in the airway, such as in the branches of the breathing tubes (bronchi), can be treated with a flexible, lighted tube called a bronchoscope and an Nd:YAG laser.

Laser-induced interstitial thermotherapy (LITT) uses heat to help shrink tumors by damaging cells or depriving them of the things they need to live (like oxygen and food). In LITT, the laser light is passed through a fiber optic wire and right into a tumor, where it heats up, damaging or killing cancer cells. LITT is sometimes used to treat tumors in the liver.

Photodynamic Therapy

In photodynamic therapy (PDT), a special drug called a photosensitizing agent is put into the bloodstream. Over time it is absorbed by body tissues. The drug stays in cancer cells for a longer time than in normal tissue. Shining a certain kind of light on the cancer cells that have the drug in them “turns on” the drug, which then kills the cancer cells.

Photosensitizing agents are turned on or activated by a certain wavelength of light. For example, an argon laser can be used in PDT. When cancer cells that contain the photosensitizing agent are exposed to red light from this laser, it causes the chemical reaction that kills the cancer cells. Light exposure must be carefully timed so that it’s used when most of the agent has left healthy cells, but is still in the cancer cells.

PDT has some advantages over other treatments:

Cancer cells can be singled out and destroyed but most normal cells are spared.

The damaging effect of the photosensitizing agent happens only when the drug is

exposed to light. The side effects are fairly mild. Still, PDT as it's currently used is not without its problems. Argon laser light cannot pass through more than about 1 centimeter of tissue (a little more than one-third of an inch), which means it's not useful against deeper tumors. And the photosensitizing agents used today can leave people very sensitive to light, causing sunburn-like reactions after only very brief sun exposure. This can greatly limit the patient's activities until the body gets rid of the drug, which often takes weeks.

PDT is sometimes used to treat cancers and pre-cancers of the swallowing tube (esophagus), and certain kinds of lung cancer that can be reached with endoscopes. PDT is being studied for use in other cancers, such as those of the brain and prostate. Researchers also are looking at different kinds of lasers and new photosensitizer drugs that might work even better.

Photodynamic Therapy

Photodynamic therapy or PDT is a treatment that uses special drugs, called photosensitizing agents, along with light to kill cancer cells. The drugs only work after they have been activated or "turned on" by certain kinds of light. PDT may also be called photo radiation therapy, phototherapy, or photo chemotherapy.

Depending on the part of the body being treated, the photosensitizing agent is either put into the bloodstream through a vein or put on the skin. Over a certain amount of time the drug is absorbed by the cancer cells. Then light is applied to the area to be treated. The light causes the drug to react with oxygen, which forms a chemical that kills the cells. PDT might also help by destroying the blood vessels that feed the cancer cells and by alerting the immune system to attack the cancer.

The period of time between when the drug is given and when the light is applied is called the drug-to-light interval. It can be anywhere from a couple of hours to a couple of days, depending on the drug used.

GYNAECOLOGY

The recent advancement in laser technology, has led to the development of new, minimally invasive treatment options for common gynaecological problems such as vaginal relaxation syndrome, urinary incontinence, pelvic organ prolapse and vaginal atrophy. Two novel treatment options called IntimaLase™ and IncontiLase™ are available. Both treatment involve the use of Erbium laser (Er:YAG) at a specific wavelength which is applied to the vaginal tissue for 10-12 minutes

How does it work?

- The laser stimulates collagen remodeling and growth of new collagen fibres (neocollagenesis) in the vagina and also along the urethra
- The end result is that the treated tissue becomes more enriched with new collagen which is tighter and more elastic.

How long does the treatment take?

- The laser treatment is done in the gynaecological practice rooms and the procedure takes approximately 10-12 minutes There is no 'cut', no pain, and no hospitalization.

5.1 HOLOGRAPHY

Basic Principle:

Holography is the science of producing holograms; it is an advanced form of photography that allows an image to be recorded in three dimensions. The Hungarian-British physicist Dennis Gabor was awarded the Nobel Prize in Physics in 1971 "for his invention and development of the holographic method". His work, done in the late 1940s, built on pioneering work in the field of X-ray microscopy by other scientists

including Mieczysław Wolfke in 1920 and WL Bragg in 1939. The discovery was an unexpected result of research into improving electron microscopes at the British Thomson-Houston (BTH) Company in Rugby, England, and the company filed a patent in December 1947 (patent GB685286). The technique as originally invented is still used in electron microscopy, where it is known as electron holography, but optical holography did not really advance until the development of the laser in 1960. The word holography comes from the Greek words hólos; "whole", grapý; "writing" or "drawing").

Holography Vs. Photography

Holography may be better understood via an examination of its differences from ordinary photography:

- A hologram represents a recording of information regarding the light that came from the original scene as scattered in a range of directions rather than from only one direction, as in a photograph. This allows the scene to be viewed from a range of different angles, as if it were still present.
- A photograph can be recorded using normal light sources (sunlight or electric lighting) whereas a laser is required to record a hologram.
- A lens is required in photography to record the image, whereas in holography, the light from the object is scattered directly onto the recording medium.
- A holographic recording requires a second light beam (the reference beam) to be directed onto the recording medium.
- A photograph can be viewed in a wide range of lighting conditions, whereas holograms can only be viewed with very specific forms of illumination.

▪

When a photograph is cut in half, each piece shows half of the scene. When a hologram is cut in half, the whole scene can still be seen in each piece. This is because, whereas each point in a photograph only represents light scattered from a single point in the scene, *each point* on a holographic recording includes information about light scattered from *every point* in the scene. It can be thought of as viewing a street outside a house through a 4 ft x 4 ft window, then through a 2 ft x 2 ft window. One can see all of the same things through the smaller window (by moving the head to change the viewing angle), but the viewer can see more *at once* through the 4 ft window.

- A photograph is a two dimensional representation that can only reproduce a rudimentary three-dimensional effect, whereas the reproduced viewing range of a hologram adds many more depth perception cues that were present in the original scene. These cues are recognized by the human brain and translated into the same perception of a three-dimensional image as when the original scene might have been viewed.
- A photograph clearly maps out the light field of the original scene. The developed hologram's surface consists of a very fine, seemingly random pattern, which appears to bear no relationship to the scene it recorded.

5.6 LASER INSTRUMENTS FOR SURGERY

Laser light is different from regular light. The light from the sun or from a light bulb has many wavelengths and spreads out in all directions. Laser light, on the other hand, has a single wavelength and can be focused in a very narrow beam. This makes it both powerful and precise. Lasers can be used instead of blades (scalpels) for very careful surgical work, such as repairing a damaged retina in the eye or cutting through body tissue.

Types of lasers

Lasers are named for the liquid, gas, solid, or electronic substance that's used to create the light. Many types of lasers are used to treat medical problems, and new ones are being tested all the time. Nowadays, 3 kinds of lasers are commonly used in cancer treatment: carbon dioxide (CO₂), argon, and neodymium: yttrium aluminum garnet (Nd:YAG).

i. Carbon dioxide (CO₂) lasers

The CO₂ laser is mainly a surgical tool. It can cut or vaporize (dissolve) tissue with fairly little bleeding as the light energy changes to heat. This type of laser is used to remove thin layers from the surface of the skin without going into the deeper layers.

ii. Argon lasers

The argon laser only goes a short distance into tissue. It's useful in treating skin problems and in eye surgery. It's sometimes used during colonoscopies (tests to look for colon cancer) to remove growths called polyps before they become cancer. It can be used with light-sensitive drugs to kill cancer cells in a treatment known as photodynamic therapy (PDT). (You can learn more about this in our document titled Photodynamic Therapy.

iii. Nd:YAG (Neodymium: Yttrium-Aluminum-Garnet) lasers

Light from this laser can go deeper into tissue than light from other types of lasers, and it can make blood clot quickly. Nd:YAG lasers can be used through thin

flexible tubes called endoscopes to get to hard-to-reach parts inside the body, such as the swallowing tube (esophagus) or large intestine (colon). This light can also travel through optical fibers, which can be bent and put into a tumor to heat it up and destroy it.

iv. Other lasers used in medicine

Some newer types of lasers – the erbium: yttrium aluminum garnet (Er:YAG); holmium: yttrium aluminum garnet (Ho:YAG), copper vapor, and diode lasers – are also being used in medical and dental treatments.

Lasers have some advantages (pros) and disadvantages (cons) compared with standard surgical tools.

Pros of laser surgery

- Lasers are more precise and exact than blades (scalpels). For instance, the tissue near a laser cut (incision) is not affected since there is little contact with skin or other tissue.
- The heat produced by lasers helps clean (sterilize) the edges of the body tissue that it's cutting, reducing the risk of infection.
- Since laser heat seals blood vessels, there is less bleeding, swelling, pain, or scarring. Operating time may be shorter.
- Laser surgery may mean less cutting and damage to healthy tissues (it can be less invasive). For example, with fiber optics, laser light can be directed to parts of the body through very small cuts without having to make a large incision.
- More procedures may be done in outpatient settings. Healing time is often shorter.

Cons of laser surgery

- Fewer doctors and nurses are trained to use lasers.
- Laser equipment costs a lot of money and is bulky compared with the usual surgical tools used. But advances in technology are slowly helping reduce their

cost and size.

- Strict safety precautions must be followed in the operating room when lasers are used.
- For example, the entire surgical team and the patient must wear eye protection.
- The effects of some laser treatments may not last long, so they might need to be repeated. And sometimes the laser cannot remove all of the tumor in one treatment, so treatments may need to be repeated.

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5.4 MEDICAL APPLICATIONS OF LASERS

The highly collimated beam of a laser can be further focused to a microscopic dot of extremely high energy density. This makes it useful as a cutting and cauterizing instrument. Lasers are used for photocoagulation of the retina to halt retinal hemorrhaging and for the tacking of retinal tears. Higher power lasers are used after cataract surgery if the supportive membrane surrounding the implanted lens becomes milky. Photo disruption of the membrane often can cause it to draw back like a shade, almost instantly restoring vision. A focused laser can act as an extremely sharp scalpel for delicate surgery, cauterizing as it cuts. ("Cauterizing" refers to long-standing medical practices of using a hot instrument or a high frequency electrical probe to singe the tissue around an incision, sealing off tiny blood vessels to stop bleeding.) The cauterizing action is particularly important for surgical procedures in blood-rich tissue such as the liver. Lasers have been used to make incisions half a micron wide, compared to about 80 microns for the diameter of a human hair.

Medicine has two prime objectives; first to detect disease at an early stage before it becomes difficult to manage and second, to treat it with high selectivity and precision without any adverse effect on uninvolved tissues. Lasers are playing a very important role in the pursuit of both these objectives. Due to their remarkable properties, lasers have made possible ultraprecise, minimally invasive surgery with reduced patient trauma and hospitalization time. The use of lasers in surgery is, by now, well established and spans virtually the entire range of disciplines: ophthalmology, gynaecology, ENT, cardiovascular diseases, urology, oncology, etc. The use of lasers for biomedical imaging and diagnostics and for phototherapy using photo activated drugs is receiving considerable current attention and is expected to have profound influence on the quality of health care.

Laser spectroscopic techniques have the promise to provide sensitive, inside, near real time diagnosis with biochemical information on the disease. These developments have the potential to change the way medical diagnosis is presently perceived. Instead of a means of solving an already known clinical problem, the diagnosis may in future screen people for problems that may potentially exist. Further, any potential risk factor so detected can be corrected with high selectivity by the use of drugs that are activated

by light. Because these drugs are inert, until photo excited by radiation with the right wavelength, the clinician can target the tissue selectively by exercising the control on light exposure (only the tissue exposed to both drug and light will be affected). A good example is the fast-developing photodynamic therapy of cancer.

There are indications that selective photo excitation of native chromophores in the tissue may also lead to therapeutic effects.

LASER AND TISSUE INTERACTIVE

Light Tissue Interactions

Radiative and non-radiative relaxation. Imagine an excited molecule that is alone, without any other nearby molecules to interact with. In this case, two things could happen. First, the energy gained by absorbing the photon, and initially stored in one mode, will begin to be shared out between all the modes in a non-radiative process of intramolecular redistribution until the molecule is in equilibrium (according to the equipartition theorem). However, the molecule could also jump abruptly to a lower energy state by emitting a photon.

If the radioactive life time of the molecule is shorter than the redistribution time, then it is likely that a photon will be emitted before the process of intra molecular redistribution has completed.

As some redistribution will always take place before a photon is emitted, the energy of the radiated photon will always be lower than the absorbed photon. There are two possible radioactive processes: fluorescence and phosphorescence. During fluorescence there is a transition from a state to a similar state, eg. singlet-singlet, and is typically fast (ns or shorter). Phosphorescence occurs after an intramolecular inter-system crossing has taken place, so the transition accompanying the radiation typically involves a change from a triplet to a singlet state which is much less likely to occur (according to quantum mechanics), and so the radiation is of lower energy and occurs over a much longer timescale (ms, seconds or even longer). All mechanisms that are not radiative are by default non radiative.

Photochemical reactions.

When the light absorption gives rise to an electronic transition, the more energetic electron will, on average, orbit the nuclei at a greater distance. As the attractive nuclear force falls rapidly with distance, the electron will be less tightly bound, and will be able to form a chemical bond with another molecule more readily. This is the basis of photochemistry.

Thermalisation, collisional relaxation

While an excited molecule is undergoing intra molecular redistribution it might collide with another molecule. Some of the vibrational energy in the excited molecule will be transferred to the colliding molecule as translational kinetic energy. Molecular translational kinetic energy is what appears at a macroscopic level as a temperature rise so leads to photo thermal effects. This process of collisional relaxation will thereby thermalize the absorbed photon energy in a matter of picoseconds, although the resulting macroscopic thermal effects occur over very much longer timescales (ms to s).

5.2 PRINCIPLE OF HOLOGRAM RECORDING

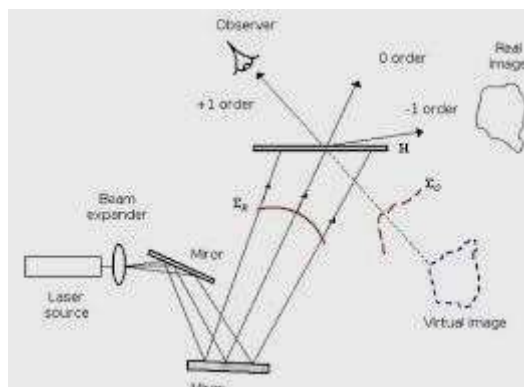


Figure 5.2.1 Hologram Recording Process

[Source: "Optical Fibre Communications" by J.M.Senior, Page:573]

Holography is a technique that enables a light field, which is generally the product of a light source scattered off objects, to be recorded and later reconstructed when the original light field is no longer present, due to the absence of the original objects.^[20] Holography can be thought of as somewhat similar to sound recording, whereby a sound field created by vibrating matter like musical instruments or vocal cords, is encoded in such a way that it can be reproduced later, without the presence of the original vibrating matter.

Laser

Holograms are recorded using a flash of light that illuminates a scene and then imprints on a recording medium, much in the way a photograph is recorded. In addition, however, part of the light beam must be shone directly onto the recording medium - this second light beam is known as the reference beam. A hologram requires a laser as the sole light source. Lasers can be precisely controlled and have a fixed wavelength, unlike sunlight or light from conventional sources, which contain many different wavelengths. To prevent external light from interfering, holograms are usually taken in darkness, or in low level light of a different color from the laser light used in making the hologram. Holography requires a specific exposure time (just like photography), which can be controlled using a shutter, or by electronically timing the laser.

Apparatus

A hologram can be made by shining part of the light beam directly onto the recording medium, and the other part onto the object in such a way that some of the scattered light falls onto the recording medium.

A more flexible arrangement for recording a hologram requires the laser beam to be aimed through a series of elements that change it in different ways. The first element is a beam splitter that divides the beam into two identical beams, each aimed in different directions:

- One beam (known as the illumination or object beam) is spread using lenses and directed onto the scene using mirrors. Some of the light scattered (reflected) from the scene then falls onto the recording medium.
- The second beam (known as the reference beam) is also spread through the use of lenses, but is directed so that it doesn't come in contact with the scene, and instead travels directly onto the recording medium.

Several different materials can be used as the recording medium. One of the most common is a film very similar to photographic film (silver halide photographic emulsion), but with a much higher concentration of light-reactive grains, making it capable of the much higher resolution that holograms require. A layer of this recording medium (e.g. silver halide) is attached to a transparent substrate, which is commonly glass, but may also be plastic.

Process

When the two laser beams reach the recording medium, their light waves, intersect and interfere with each other. It is this interference pattern that is imprinted on the recording medium. The pattern itself is seemingly random, as it represents the way in which the scene's light interfered with the original light source but not the original light source itself. The interference pattern can be considered an encoded version of the scene, requiring a particular key — the original light source in order to view its

This missing key is provided later by shining a laser, identical to the one used to record the hologram, onto the developed film. When this beam illuminates the hologram, it is diffracted by the hologram's surface pattern. This produces a light field identical to the one originally produced by the scene and scattered onto the hologram.

The image this effect produces in a person's retina is known as a virtual image.

CONDITION FOR RECORDING A HOLOGRAM

A suitable object or set of objects a suitable laser beam part of the laser beam to be directed so that it illuminates the object (the object beam) and another part so that it illuminates the recording medium directly (the reference beam), enabling the reference beam and the light which is scattered from the object onto the recording medium to form an interference pattern a recording medium which converts this interference pattern into an optical element which modifies either the amplitude or the phase of an incident light beam according to the intensity of the interference pattern.

An environment which provides sufficient mechanical and thermal stability that the interference pattern is stable during the time in which the interference pattern is recorded. The object should be fully exposed to radiation. The photographic plate should have i) high resolution ii) high sensitivity iii) wide spectral range.

5.3 RECONSTRUCTING AND VIEWING THE HOLOGRAPHIC IMAGE

When the hologram plate is illuminated by a laser beam identical to the reference beam which was used to record the hologram, an exact reconstruction of the original object wave front is obtained. An imaging system (an eye or a camera) located in the reconstructed beam 'sees' exactly the same scene as it would have done when viewing the original. When the lens is moved, the image changes in the same way as it would have done when the object was in place. If several objects were present when the hologram was recorded, the reconstructed objects move relative to one another, i.e. exhibit parallax, in the same way as the original objects would have done. It was very common in the early days of holography to use a chess board as the object and then take photographs at several different angles using the reconstructed light to show how the relative positions of the chess pieces appeared to change.

A holographic image can also be obtained using a different laser beam configuration to the original recording object beam, but the reconstructed image will not match the original exactly. When a laser is used to reconstruct the hologram, the image is speckled just as the original image will have been. This can be a major drawback in viewing a hologram.

White light consists of light of a wide range of wavelengths. Normally, if a hologram is illuminated by a white light source, each wavelength can be considered to generate its own holographic reconstruction, and these will vary in size, angle, and distance. These will be superimposed, and the summed image will wipe out any information about the original scene, as if superimposing a set of photographs of the same object of different sizes and orientations. However, a holographic image can be obtained using white light in specific circumstances, e.g. with volume holograms and rainbow holograms. The white light source used to view these holograms should always approximate to a point source, i.e. a spot light or the sun. An extended source (e.g. a fluorescent lamp) will not reconstruct a hologram since its light is incident at each point at a wide range of angles, giving multiple reconstructions which will "wipe" one another out.

HOLOGRAPHIC NON-DESTRUCTIVE TESTING

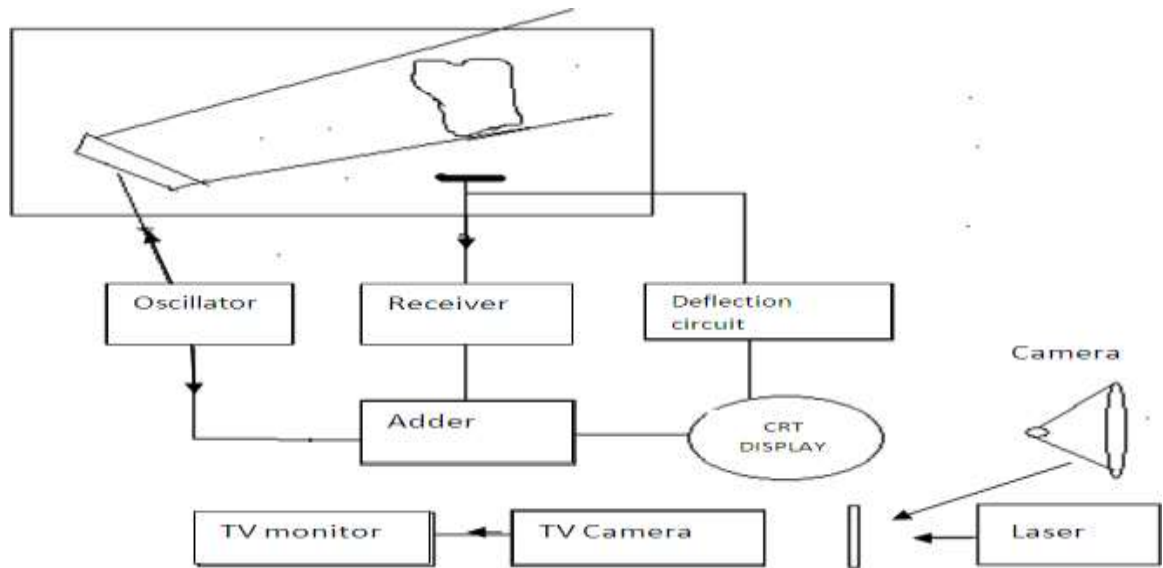


Figure 5.3.1 Material Removal Process

[Source: "Optical Fibre Communications" by J.M.Senior, Page:591]

A single large ultrasonic transducer which sends out ultrasonic waves towards the object under study and it scans the object. The scattered waves from the object from the object waves. A received transducer collects the scattered object wave and converts them into electrical signals. The reference electrical waves are given by the RF oscillator and these object to reference waves are made to interference by the electronic adder. The interference pattern is formed on the fluorescent screen of the cathode photographic film is developed.

The developed photographic film serves as a hologram. The hologram is illuminated by a low power laser like He- Ne laser which acts as the optical reference source. The T.V camera takes the videograph of the 3 D image of the object and it displays on the T.V monitor

Applications of holographic interferometry	
Field	Applications
Aerospace	Defects in honeycomb plates Testing of construction materials,

	Testing of welding methods Inspection of rocket bodies Flow visualization in wind tunnels Vibration modes of turbine blades
Automobiles	Testing of oil pressure sections Testing of welding methods Research in construction of automobile bodies Construction of engines
Machine tools and precision instruments	Measurement of deformations of machine parts, jigs and tools Measurement inside cylinders Measurements of stiffness (heat, static or dynamic) Analysis of construction of instruments and tools
Electrical and electronic industries	Vibration modes of turbine blades, motors, transformers, loudspeakers Testing of welding and adhesion Testing of circuit parts Analysis of audio equipments Leak test of batteries
Civil Engineering	Analysis of constructions Design of pipes Research in concrete.
Chemical industry	Measurement of mixed fluids. Tyre, rubber and NDT of tyres, plastics Testing of molded products Measurement of adhesion defects
Medicine	Measurement on living bodies Chest deformation due to inhalation Measurement on teeth and bones Testing materials for dental surgery

	Testing of urinary track Measurement on eyes, ears, etc.
Musical instruments	Measurement of vibration modes
Cultural articles and paintings	NDT and restoration.

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5.7 REMOVAL OF TUMORS OF VOCAL CORDS

Vocal cord surgery is performed when the vocal cords have growths such as polyps, tumours or other masses that need to be removed for biopsy to improve function. It is also performed to normalize vocal cord functioning when vocal cords are scarred from various causes or otherwise abnormal. These conditions may interfere with the complete opening and closing of the vocal cord, which is necessary for normal speech and breathing.

Performing of vocal cord surgery:

Surgery on the vocal cords can be performed either directly in an open surgical approach by making an incision in the neck or indirectly through an endoscopic approach through a tube inserted into the mouth and throat. Either procedure is performed under general anesthesia i.e the person is fully asleep.

Brain Surgery

A brain tumor diagnosis is overwhelming under any condition, but it can be worse if surgery is not an option. When tumors are in hard-to-reach brain areas or are close to areas that control vital functions, traditional surgery may be too risky. Now, however, Cleveland Clinic neurosurgeons have a potentially life-extending surgical option for patients with brain tumors once considered inoperable. If you have been told that you have an inoperable primary or metastatic brain tumor

Destroying Cancer Cells with Laser-Directed Heat

Laser interstitial thermal therapy (LITT) transmits heat to coagulate, or “cook,” brain tumors from the inside out. This technology is not new in cancer treatment, but early approaches posed challenges with limiting the laser energy only to tumors. NeuroBlate system, the surgeon can “steer” and monitor the effects of the laser beam, thus sparing surrounding healthy tissue. Unlike conventional open surgery, this therapy is minimally invasive. It takes place with the patient in an MRI machine because the laser system is guided, positioned and monitored with MRI.

Surgical techniques

The patients will be placed under general anesthesia. With great precision, a thin, high-intensity laser probe will be inserted through a small hole in your skull, deep into your brain. The tip of the probe emits laser energy sideways, heating and destroying brain tumor tissue in one direction while cooling to remove heat and protect normal tissue in neighboring areas. Each burst of laser energy lasts from 30 seconds to a few minutes.

The laser generates heat up to 160 degrees Fahrenheit, which is sufficient to coagulate and kill the tumor cells.

- On a computer screen, the surgeon will monitor the tumor destruction as it occurs.

An MRI thermometry measures temperature in and around the tumor, providing valuable feedback to the surgeon throughout the procedure. Quick recovery is possible with very few days of hospitalization.

Advantage

Is less invasive than even the most minimally invasive open operations. Enhances patient safety. Promotes quicker recovery. Has the potential to help some patients whose tumors had been considered too risky to treat, whose tumors did not respond to alternate treatments or who had otherwise been deemed poor candidates for surgery. Offers a therapeutic option when radiosurgery fails. May allow for multiple treatments. Is less costly than traditional surgery.

PLASTIC SURGERY

Goal

Correction of disfigurement. Restoration of impaired function. Improvement of physical appearance.

Procedure in plastic surgery:

- Tissue may be moved to fill a depression, to cover a wound, or to improve appearance.
- Tissue may be completely removed to alter the contours of a feature.

5.5 TYPES OF INTERACTIONS

There are many different mechanisms by which laser light can interact with tissue, and these have been categorized in a number of different ways by different authors. For the purposes of these lectures, the most common interaction mechanisms for therapeutic and surgical applications will be divided into

1. **Photochemical reactions:** when a molecule absorbs a photon of sufficient energy, the energy can be transferred to one of the molecule's electrons. An electron with higher energy can more easily escape the nuclear forces keeping it close to the nucleus, and so excited molecules (which are molecules with an electron in a higher energy state) are more likely to undergo chemical reactions (exchanging or sharing of electrons) with other molecules. In photodynamic therapy, for instance, a photo sensitizing drug (a concoction of molecules which, when they absorb light, cause reactive oxygen species to form) is used to cause necrosis (cell death) and apoptosis ('programmed' cell death). Photodynamic therapy is increasingly widely used in oncology to destroy cancerous tumours.
2. In photo thermal interactions, the energy of the photons absorbed by chromophores (a term used to refer to any light-absorbing molecules) is converted into heat energy via molecular vibrations and collisions, which can cause a range of thermal effects from tissue coagulation to vaporization. Applications include tissue cutting and welding in laser surgery, and photo acoustic imaging.
3. In photoablation, high-energy, ultraviolet (UV) photons are absorbed by electrons, raising them from a lower energy 'bonding' orbital to a higher energy 'non-bonding' orbital, thereby causing virtually immediate dissociation of the molecules. This naturally leads to a rapid expansion of the irradiated volume and ejection of the tissue from the surface. This is used in eye (corneal) surgery, among other applications.

4. In plasma-induced photoablation a free (sometimes called 'lucky') electron is accelerated by the intense electric field which is found in the vicinity of a tightly focussed laser beam. When this very energetic electron collides with a molecule, it gives up some of its energy to the molecule. When sufficient energy is transferred to free a bound electron, a chain reaction of similar collisions is initiated, resulting in a plasma: a soup of ions and free electrons. One application of this is in lens capsulotomy to treat secondary cataracts.
5. The final set of related mechanisms, grouped under the term photo disruption, are the mechanical effects that can accompany plasma generation, such as bubble formation, cavitation, jetting and shockwaves. These can be used in lithotripsy (breaking up kidney or gall stones), for example.

SELECTING AN INTERACTION MECHANISM

1. The type of molecules the tissue is made of and contains. These determine the energy levels - the energies of photons that can be absorbed - and the available de-excitation pathways, ie. the routes through which the energy leaves the state into which it was absorbed, to end up as heat or perhaps another photon. The frequency (or wavelength) of the light, ie. the energy associated with each individual photon,
2. The power per unit area delivered by the laser,
3. The duration of the illumination, and repetition rate of the pulses for a pulsed laser. Because different interaction mechanisms dominate under different conditions (photoablation requires UV light, photo disruption requires very short duration pulses, etc), by carefully choosing the laser characteristics the interaction can be restricted to a specific mechanism, and therefore a specific effect on the tissue. Lasers are therefore useful for medical applications because:
 - a. the energy of the photons can be chosen, as each type of laser will emit photons of only one energy (one frequency or wavelength).

- b.** the power can be carefully controlled over a wide range of influence rates,
- 4. The beam shape can be well controlled (focused, collimated, etc.), and the duration of the laser pulses can range from as-long-as-you-like to less than 100 femtoseconds. (100 femtoseconds is really quite a short time. It is about the time it
- 5. takes light to travel the thickness of a human hair.)

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