Nadar Saraswathi College of Engineering & Technology

NSCET E-LEARNING PRESENTATION

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

IV YEAR / VII SEMESTER

EI8075 – FIBRE OPTICS AND LASER INSTRUMENTATION

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UNIT 04

HOLOGRAM AND MEDICAL APPLICATIONS

UNIT V HOLOGRAM AND MEDICAL APPLICATIONS

Holography: Basic Principle, Holography vs. photography, Principle Of Hologram Recording, Condition For Recording A Hologram, Reconstructing and viewing the holographic image– Holography for non-destructive testing – Holographic components – Medical applications of lasers, laser-Tissue Interactions Photochemical reactions, Thermalisation, collisional relaxation, Types of Interactions and Selecting an Interaction Mechanism – Laser instruments for surgery, removal of tumors of vocal cards, brain surgery, plastic surgery, gynaecology and oncology..

Holography Basic Principle

• This is the process of image construction by recording and reconstruction of hologram by means of interference techniques without the aid of lenses

• Another Lensless photography

•Recording of optical image is done by means of Interference techniques without using lenses

•Holes – The Whole (Greek Word)

•Holography is the science of producing holograms; it is an advanced form of photography that allows an image to be recorded in three dimensions

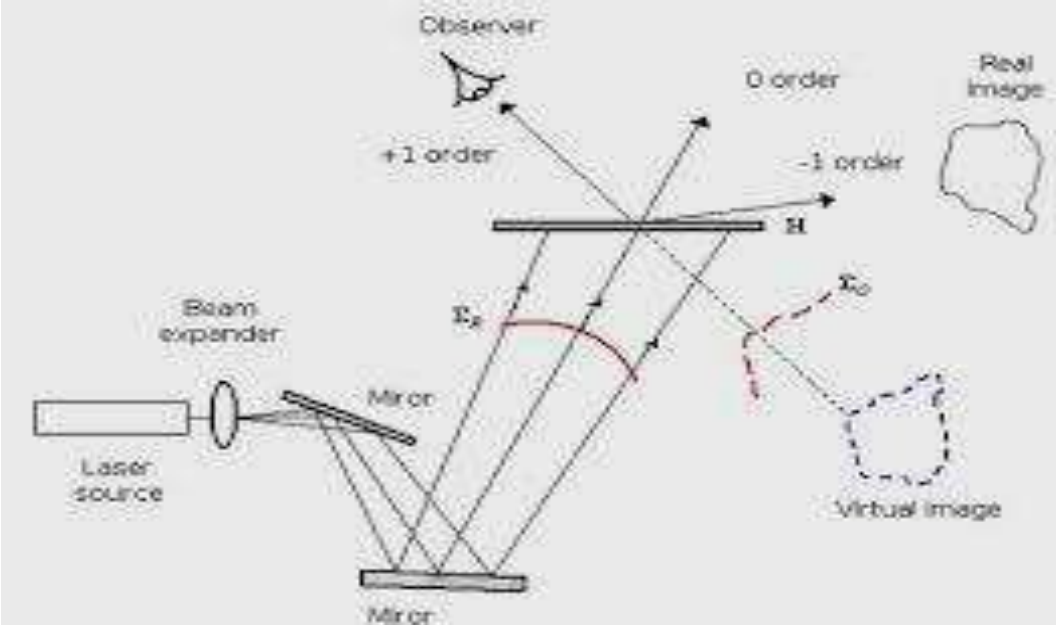
Holography vs. photography

•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.
- 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.

- **Principle Of Hologram Recording**



•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.

• 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.

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:

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.

• 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

- suitable object or set of objects
- 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

- 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.

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.

•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.

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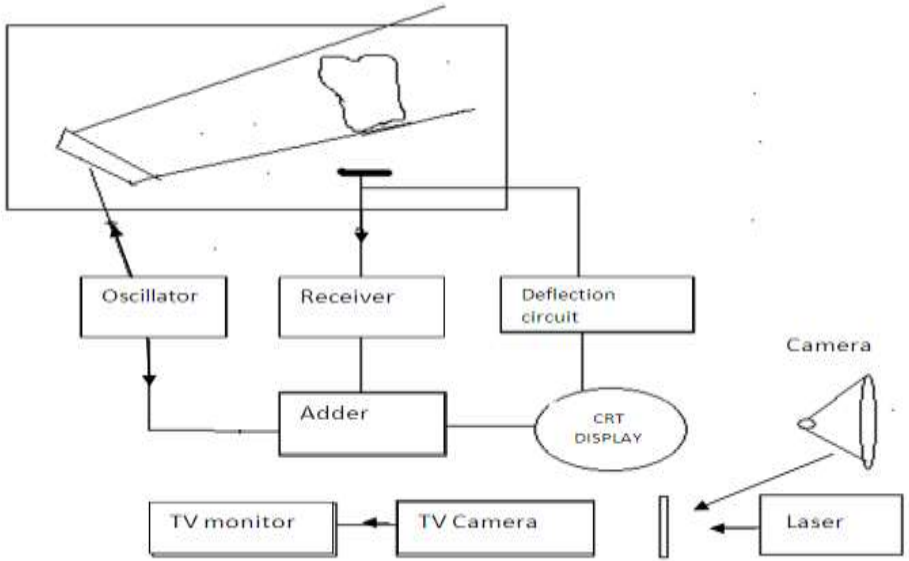
Holographic Non-Destructive Testing



• 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	Application
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

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 anon-radiative process of intra molecular redistribution until the molecule is in equilibrium

•However, the molecule could also jump abruptly to a lower energy state by emitting a photon.

• If the radioactive lifetime 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 there radiated photon will always be lower than the absorbed photon.

•Two possible radiative processes: fluorescence and phosphorescence.

• During fluorescence there is a transition from a state to a similar state, eg. singlet-singlet, and is typically fast .

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 o rapidly with distance, the electron will be less tightly bound, and will be able to form a chemical bond with another molecule more readily.

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 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 photothermal effects.

• This process of collisional relaxation will thereby thermalise the absorbed photon energy in a matter of picoseconds, although the resulting macroscopic thermal effects occur over very much longer timescales (ms to s).

Types of Interactions

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 are more likely to undergo chemical reactions with other molecules. In photodynamic therapy, for instance, a photo sensitising drug 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. Inphotothermalinteractions, the energy of the photons absorbed by chromopores (a term used to refer to any light-absorbing molecules) is converted into heat energy via molecular vibrations and collisions .Applications include tissue cutting and welding in laser surgery, and photo acoustic imaging.

3.Inphotoablation, 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 is used in eye (corneal) surgery, among other applications.

4. In plasma-induced photoablationa 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 energyto the molecule.

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,

2. The frequency (or wavelength) of the light, ie. the energy associated with each individual photon,

3. The power per unit area delivered by the laser,

4. The duration of the illumination, and repetition rate of the pulses for a pulsed laser.

• Because different interaction mechanisms dominate under different conditions (photo ablation requires UV light, photo disruption requires very short duration pulses, etc),

•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,

c. 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 fem to seconds. (100 fem to seconds is really quite a short time.

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

• 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).

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); holium: 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.

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.

• 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.

Removal Of Tumors Of Vocal Cards

• 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 perform 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 of 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.

• Unlike conventional open surgery, this therapy is minimally invasive. It takes place with the patient inan 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 side ways, 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. A 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

•Less invasive than even the most minimally invasive open operations

•Enhances patient safety

•Promotes quicker recovery

•Offers a therapeutic option when radio surgery fails

•May allow for multiple treatments

•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**.**

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 photosensitizing 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.

• 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.

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.

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.

Gynaecology

• The recent advancement in laser technology, has led to the development of new, minimally invasive treatment options for common gynacological problems such as vaginal relaxation syndrome, urinary incontinence, pelvic organ prolapse and vaginal atrophy.

• Two novel treatment options called IntimaLaseTMand In contiLaseTMare 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.

working

• 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.

Treatment

• The laser treatment is done in the gynecological practice rooms and the procedure takes approximately 10-12 minutes

• There is no ‘cut’, no pain, and no hospitalization