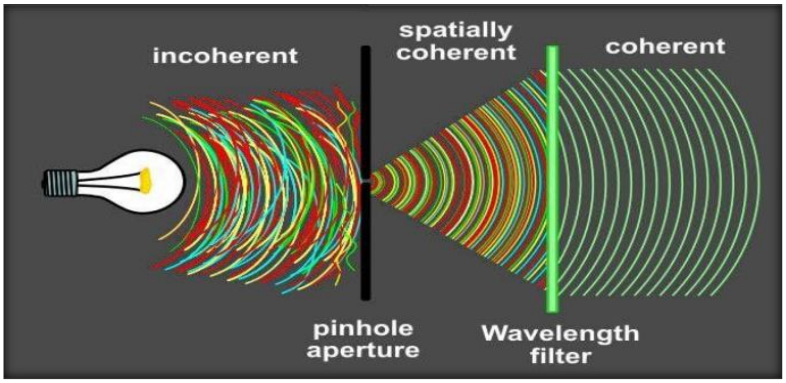
(Biomedical Optics)

1-Introduction to Coherence Theory

Two wave sources are considered coherent if they have the same frequency and waveform. Coherence is an ideal property that enables stationary interference, meaning interference that remains constant in time and space (i.e. temporally and spatially interference is constant).

- **Temporal Coherence:** It refers to the degree of correlation between the phases of the waves at different points in time. Two sources are temporally coherent if the phase relationship between them remains constant over time. Lasers are an example of a nearly temporally coherent light source.
- **Spatial Coherence:** It refers to the degree of correlation between the phases of the waves at different points in space. Two sources are spatially coherent if their wavefronts maintain a constant phase relationship across different points in space. Laser light is often spatially coherent as well.
- Both aspects are crucial in understanding and characterizing the behavior of light waves.

More generally, coherence describes all properties of the correlation between physical quantities of a single wave, or between several waves or wave packets.



2-Coherence Imaging

Coherence imaging refers to a set of advanced imaging techniques that utilize the principles of coherence in optics to produce high-resolution and detailed images of objects or tissues. Coherence imaging methods exploit the interference patterns created by coherent light to gather detailed information about the structure, composition, or properties of objects. These techniques are applied across various fields, including medical diagnostics, materials science, and non-destructive testing, due to their ability to produce high-quality, detailed images with valuable information.

3- Applications to Optical Coherence Tomography (OCT)

Optical Coherence Tomography (OCT): is non-invasive medical imaging technique. This is advantageous for imaging internal structures without causing harm to the patient. OCT operates on the principle of low-coherence interferometry. It uses a broadband light source, typically near-infrared light, to create interference patterns when directed onto a tissue (near-infrared light is used because it can penetrate biological tissues to a certain depth, allowing imaging of structures under the surface).

- A fiber optic probe is used to direct light waves onto the tissue being imaged. The probe contains a single-mode optical fiber that emits near-infrared light waves and collects the backscattered light reflected from the tissue. The single-mode optical fiber collects the backscattered light, which carries information about the internal structure of the tissue.
- Low-coherence interferometry allows OCT to measure the time delay between the reference light and the light scattered back from various tissue layers. This time delay provides depth information, allowing the creation of detailed cross-sectional images.

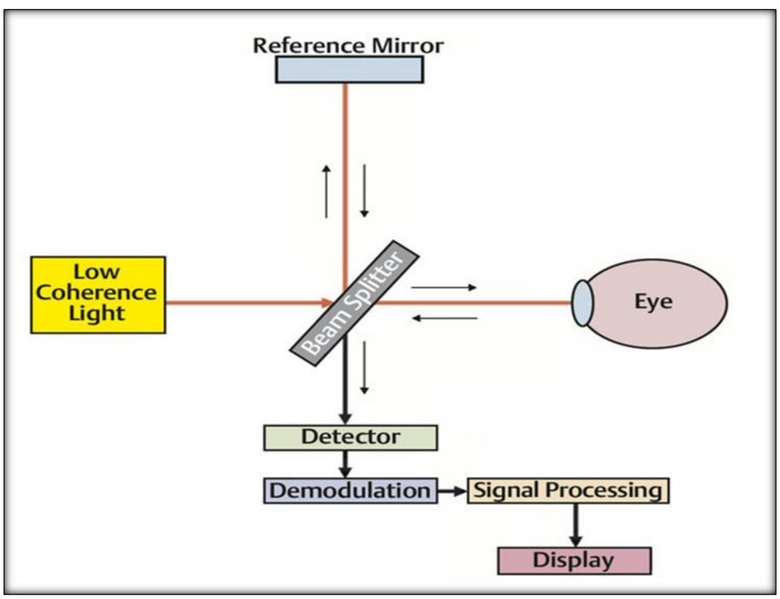


Figure: Optics in optical coherence tomography. Near-infrared low-coherence light is directed onto a beam splitter, from which one beam is incident onto the eye;

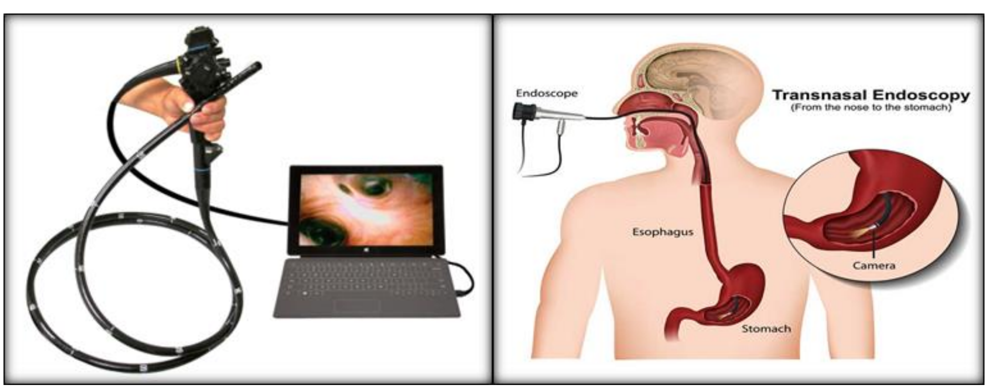
the second beam travels a reference path (reference mirror). The backscattered light from the eye is interfered with the reflected light from the reference arm and detected with a photodetector. It then undergoes demodulation and processing at the output of the interferometer.

- **Advantages:**

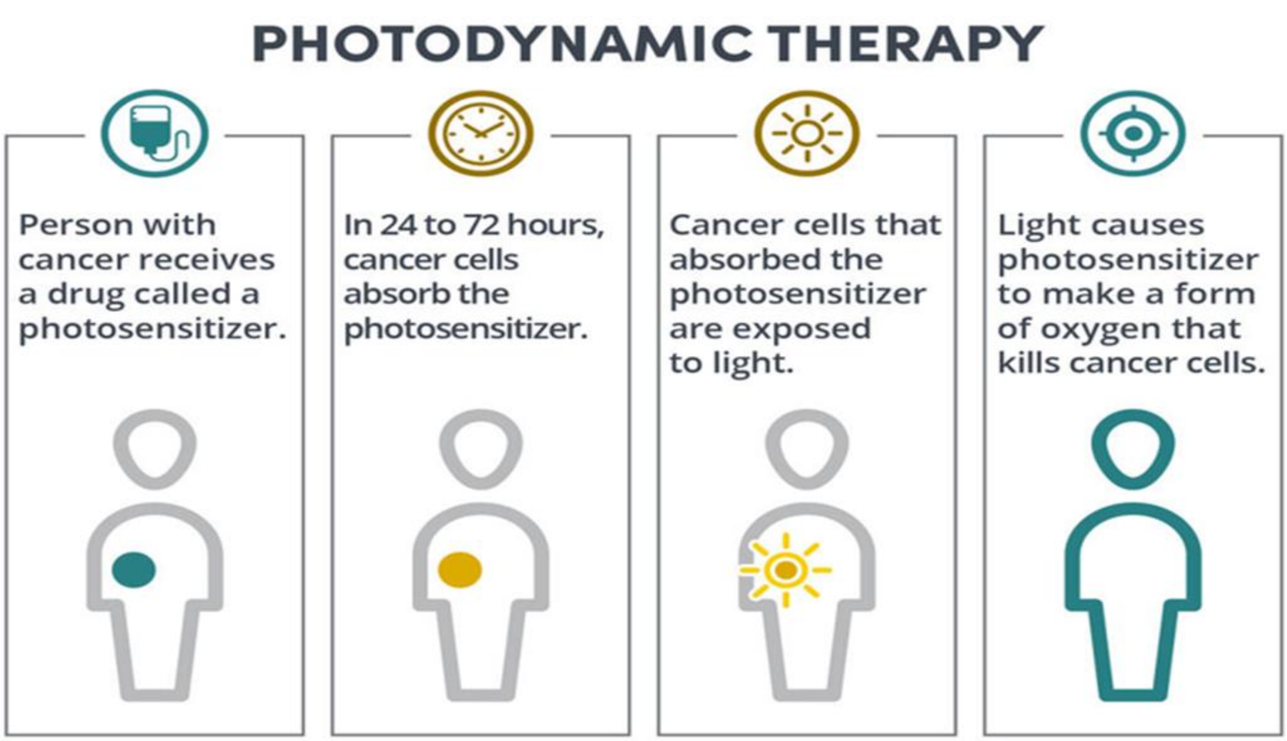
1) **Non-Invasive:** OCT is non-invasive, allowing for imaging without the need for surgical procedures.
2) **High Resolution:** OCT provides high-resolution images, enabling the visualization of fine structures within tissues.
3) **Real-Time Imaging:** In some applications, OCT can provide real-time imaging, allowing for dynamic monitoring of changes.

- **Applications:**

OCT is widely used in various medical fields, including: **Ophthalmology** for retinal imaging, **Cardiology** for imaging blood vessels, **Dermatology** for skin imaging, and **Endoscopy** for imaging internal organs in real-time.



4-Photodynamic therapy (PDT): is a medical treatment that uses fiber optic cables to deliver light to cancer cells that have been targeted with photosensitizing drugs. The light activates the drugs, causing the cancer cells to die. Photosensitizers are activated by a specific wavelength of light energy, usually from a laser. The photosensitizer is nontoxic until it is activated by light. However, after light activation, the photosensitizer becomes toxic to the targeted tissue. (PDT) has several advantages, for example, PDT is minimally invasive, meaning it doesn't require major surgical procedures, does not require general anesthesia, and has fewer side effects. Moreover, PDT can be used to treat a wide range of cancers, including skin, lung, bladder, and brain cancer. Additionally, PDT may not be suitable for certain types of cancers or advanced stages of the disease.



5- Laser Characteristics as applied to medicine and biology- Laser tissue Interaction

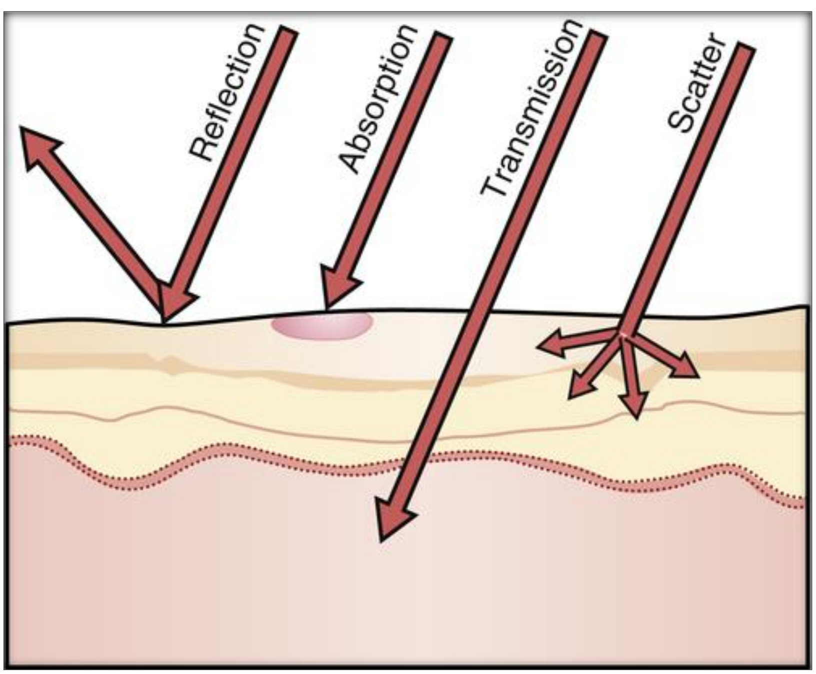
Laser (Light Amplification by Stimulated Emission of Radiation) have unique characteristics that make them valuable tools in medicine and biology. Laser-tissue interaction involves the interaction of laser light with biological tissues. Here are some key laser characteristics and their applications in medicine and biology:

1) Monochromaticity (having a single color or wavelength).
2) Coherence (having waves that are in phase with each other).
3) Directionality (being able to focus the light into a narrow beam).
4) Power: Lasers can produce high-intensity light, which can be used to ablate, vaporize, or coagulate tissue.
5) Pulse duration: Lasers can produce light pulses of very short duration, which can be used for imaging or to deliver precise amounts of energy to specific tissues or cells.

the unique properties of lasers, make laser light particularly useful for precise surgical procedures, imaging, and therapeutic applications in medicine and biology.

6- OPTICAL PROPERTIES OF THE TISSUES (Refraction, Scattering, Absorption, Light transport inside the tissue)

Laser tissue interaction refers to the ways in which laser light interacts with biological tissues. When laser light interacts with biological tissue, it can be absorbed, scattered, or transmitted depending on the properties of the tissue and the wavelength of the light. **Absorption** of laser light can cause heating and damage to tissue, which can be used for surgical procedures such as cutting or ablation. **Scattering** of laser light can be used for imaging and diagnostic purposes, such as in confocal microscopy. **Transmitted** laser light can be used for therapeutic purposes, such as in photodynamic therapy for cancer treatment. In this method, light-sensitive drugs are activated by laser light, selectively destroying cancer cells.



- The interaction of laser light with biological tissues also depends on the properties of the tissue, such as its refractive index, absorption coefficient, and scattering coefficient.
- Different types of tissues, such as skin, bone, and muscle, have different optical properties that can affect the way laser light interacts with them.