First lecture

What is Photonics

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What is Photonics

Photonics is the science and technology of generating, controlling, and detecting photons, which are particles of light. Photonics underpins technologies of daily life from smartphones to laptops to the Internet to medical instruments to lighting technology. The 21st century will depend as much on photonics as the 20th century depended on electronics. This page will contain links and resources to let you learn about photonics and understand its impact on the world.

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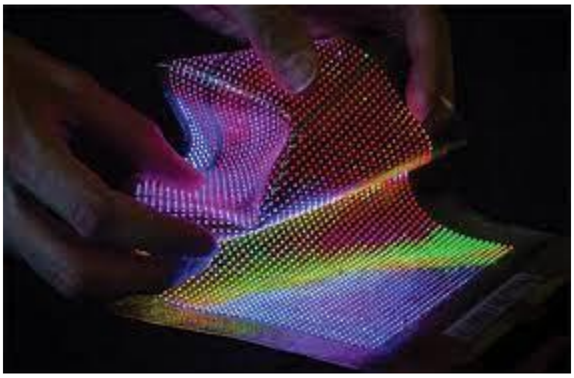

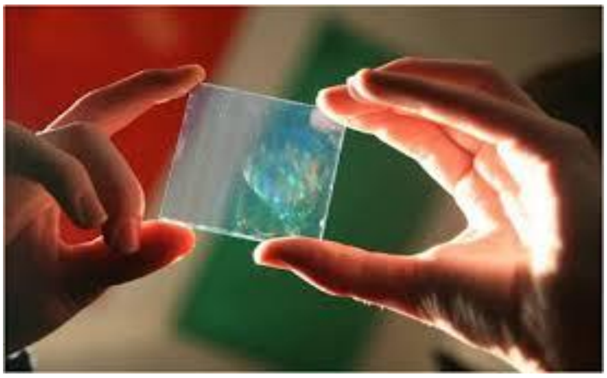

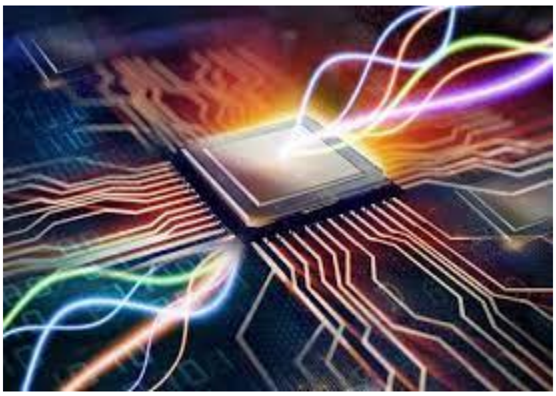

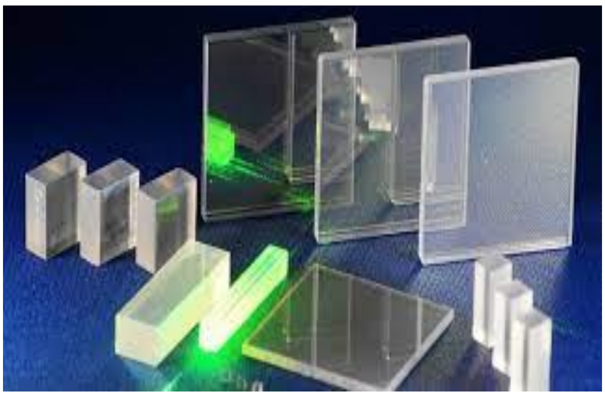

Introduction:

- Light is electromagnetic radiation. The word light is used to denote radiation that may be visible to the human eye or invisible. In fact, as we will see later, only a very small portion of the electromagnetic spectrum lies in the visible range.

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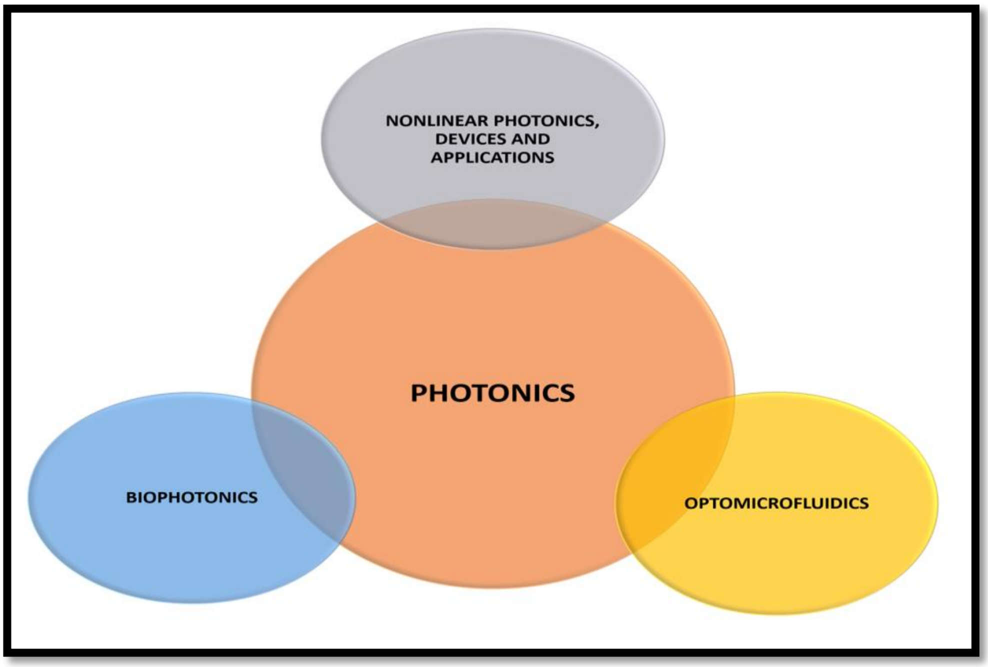
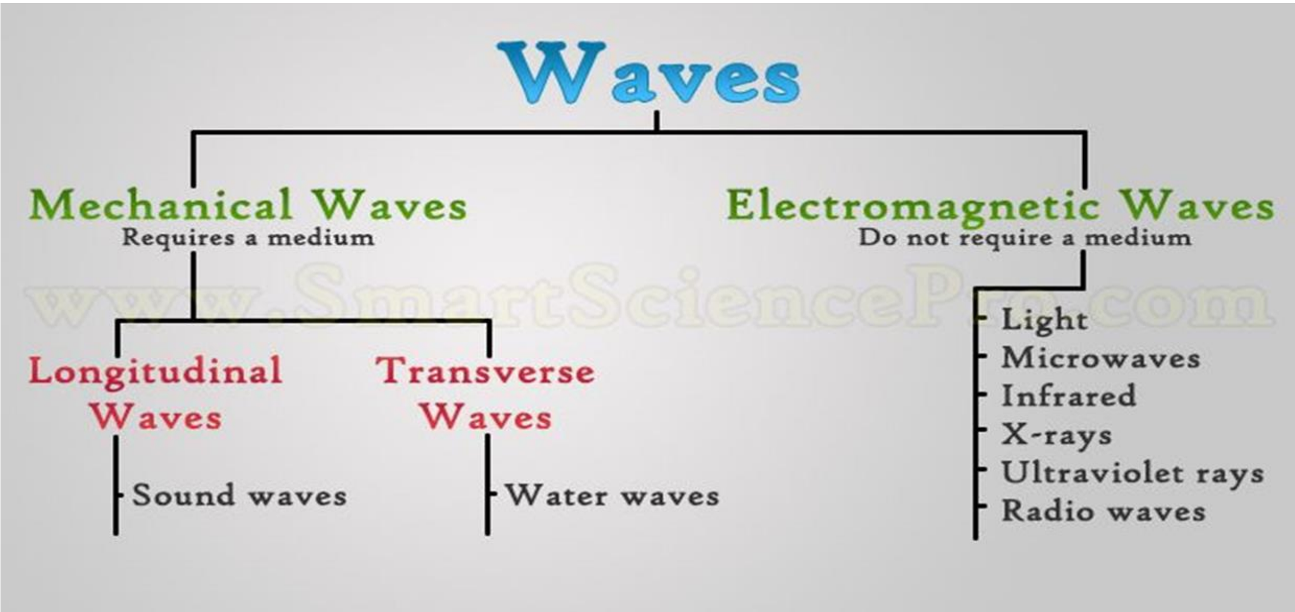


Waves

- The concept of the wave is used to express the transmission of energy. A wave is a loosening of a medium in which energy travels through this medium without moving matter. In a wave, the particles of the medium are temporarily displaced and then return to their original position.



Relationship to other fields:

Classical optics

Photonics is closely related to optics. Classical optics long preceded the discovery that light is quantized, when Albert Einstein famously explained the photoelectric effect in 1905. Optics tools include the refracting lens, the reflecting mirror, and various optical components and instruments developed throughout the 15th to 19th centuries.

Key tenets of classical optics, such as Huygens Principle, developed in the 17th century, Maxwell's Equations and the wave equations, developed in the 19th, do not depend on quantum properties of light.

Modern optics

Photonics is related to quantum optics, optomechanics, electro-optics, optoelectronics and quantum electronics. However, each area has slightly different connotations by scientific and government communities and in the marketplace. Quantum optics often connotes fundamental research, whereas photonics is used to connote applied research and development.

The term photonics more specifically connotes:

- The particle properties of light.
- The potential of creating signal processing device technologies using photons.
- The practical application of optics, and An analogy to electronics

Overview of photonics:

The science of photonics includes investigation of the emission, transmission, amplification, detection, and modulation of light.

Light sources

Photonics commonly uses semiconductor-based light sources, such as light-emitting diodes (LEDs), super luminescent diodes, and lasers. Other light sources include single photon sources, fluorescent lamps, cathode ray tubes (CRTs), and plasma screens. Note that while CRTs, plasma screens, and organic light-emitting diode displays generate their own light, liquid crystal displays (LCDs) like TFT screens require a backlight of either cold cathode fluorescent lamps or, more often today, LEDs.

Transmission media

Light can be transmitted through any transparent medium. Glass fiber or plastic optical fiber can be used to guide the light along a desired path. In optical communications optical fibers allow for transmission distances of more than 100 km without amplification depending on the bit rate and modulation format used for transmission.

Amplifiers

Optical amplifiers are used to amplify an optical signal. Optical amplifiers used in optical communications are erbium-doped fiber amplifiers, semiconductor optical amplifiers, Raman amplifiers and optical parametric amplifiers, semiconductor optical amplifiers, Raman amplifiers and optical parametric amplifiers. A very advanced research topic on optical amplifiers is the research on quantum dot semiconductor optical amplifiers.

Detection

Photo detectors detect light. Photo detectors range from very fast photodiodes for communications applications over medium speed charge coupled devices (CCDs) for digital cameras to very slow solar cells that are used for energy harvesting from sunlight. There are also many other photo detectors based on thermal, chemical, quantum, photoelectric and other effects. Photo detectors detect light.

Modulation

Modulation of a light source is used to encode information on a light source. Modulation can be achieved by the light source directly. One of the simplest examples is to use a flashlight to send Morse code. Another method is to take the light from a light source and modulate it in an external optical modulator.

Introduction to Wave plates

The interaction of light with the atoms or molecules of a material is wavelength dependent. A result of this dependence is the resonant interactions related to material dispersion. Birefringence is another consequence of such resonant interaction, which is the change in refractive index with the polarization of light. The orderly arrangement of atoms in some crystals results in different resonant frequencies for different orientations of the electric vector relative to the crystalline axes. In turn, this results in different refractive indices for different polarizations.

Plate types

- Half-wave plate]
- Quarter-wave plate
- Full-wave, or sensitive-tint plate
- Multiple-order vs. zero-order wave plates

Wave plates

By taking just the right slice of a crystal with respect to the crystalline axes, it can be arranged so that the minimum index of refraction is exhibited for one polarization of the electric vector of a linearly polarized wave, as shown in Figure 3. The wave is polarized along the fast axis, since its phase velocity will be a maximum.

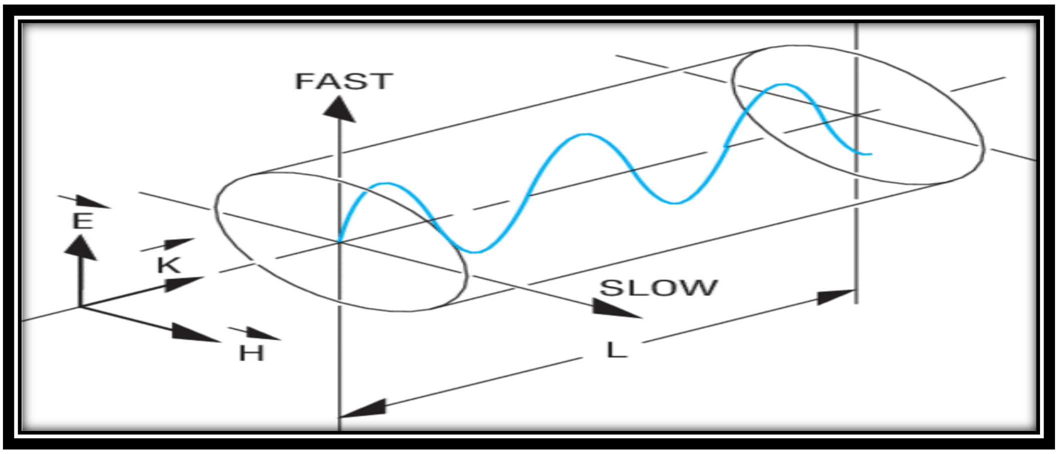


Figure 3. A wave is polarized along the fast axis.

A linearly polarized wave with its plane rotated 90° will propagate with the maximum index of refraction and minimum phase velocity, as shown in Figure 4. This wave is polarized along the slow axis.

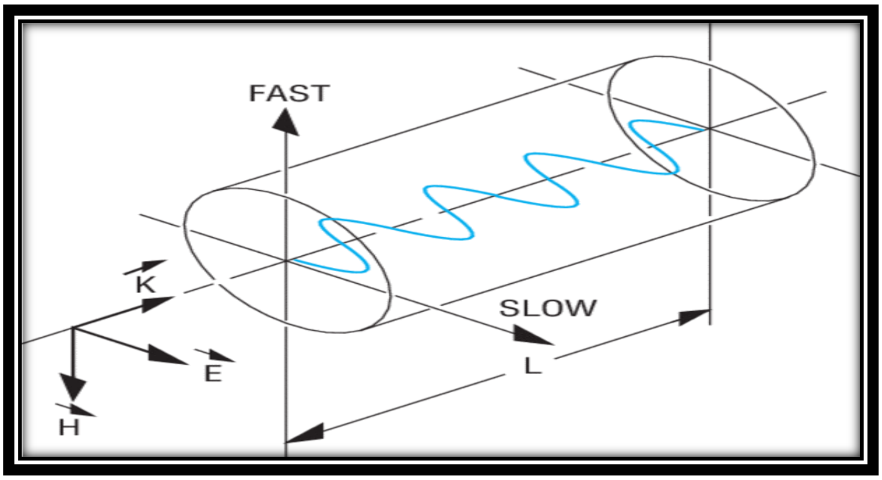


Figure 4. A wave is polarized along the slow axis.

Half-Wave plates

The most commonly used wave plates are the half-wave plate ($\Gamma = \pi$) and the quarter-wave plate ($\Gamma = \pi/2$). Half-wave plates can be used to rotate the plane of linearly polarized light as shown in Figure 5.

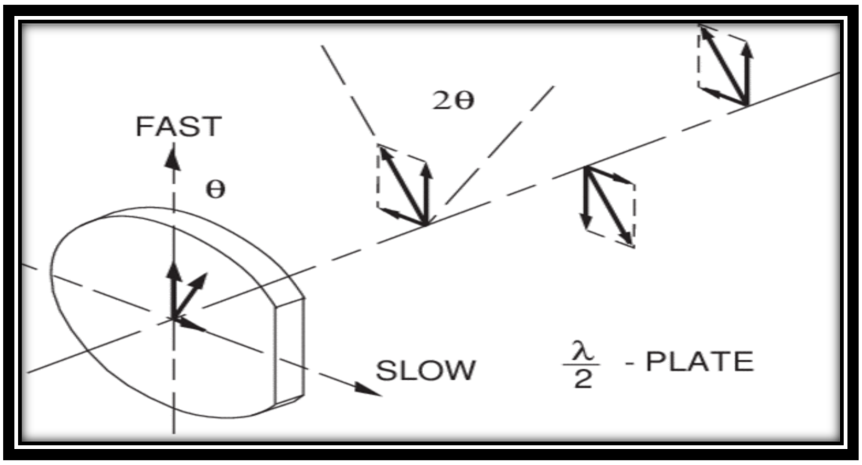


Figure 5. A half-wave plates rotating the plane of linearly polarized light.