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A Review of Polarization of light, and its applications

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Abstract:

Controlling and manipulating the polarization of light is crucial for many optical applications.Optical designs frequently focus on the wavelength and intensity of light, often neglecting its polarization. Polarization is an important property of light that affects even those optical systems that do not explicitly depends on it. The polarization of light plays a major role in the focusing of laser beams, affects the cut-off wavelengths of waveguides, and can be important to prevent unwanted signal losses. Polarization measurements are important in many metrology applications such as stress analysis in glass or plastic, pharmaceutical ingredient analysis, and biological microscopy. Different polarizations of light can also be absorbed to different depths by materials, an essential property for LCD screens, 3D movies, and your glare-reducing sunglasses. This paper is a review article of Polarization, shedding light on the ways to manipulate and control polarization of the incident light and diversified applications of this wonderful optical phenomenon.

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Introduction

Understanding the dynamics of light is becoming increasingly important in the study of laser physics, non-linear optics and fiber optics industry. One of the most fundamental property that affects the behaviour of light as it propagates in a medium and from one medium to other is polarization. Polarization of light is a phenomenon that depends on the fact that the electric field of the light is a vector, that is, the direction of oscillation plays a very important role. Light is linearly polarized (also referred to as plane polarized) when the electric field is oscillating in a straight line. When the tip of the electric field vector traces an ellipse, the light is elliptically polarized. When the tip of the electric field vector traces a circle, then we have circular Polarization. If the light is not perfectly monochromatic, so that the direction of vibration of electric field vector is changing constantly the light is said to be unpolarized.

There are some substances for which the refractive index is different for linearly polarized lights in different direction. For example consider a material with asymmetrical molecules whose length is larger than it's width and let these molecules be arranged with their lengths parallel. When an oscillating electric field passes through this substance then electrons of the substance vibrate more readily in the direction parallel to the length of the molecules than along the width. The direction of the length of the molecules is called as optic axis. The refractive index is different when the polarization is along the optic axis than it would be if the direction of polarization be perpendicular to it. Such types of substances that have two indices of refraction, that depend on the direction of polarization of light are called as birefringent materials. If we shine a polarized light on this substance at an angle of 45° to the optic axis, this light is a superposition of x and y components that are polarized perpendicular to each other that are of equal amplitude and are in phase. Inside the material, both the components travel with different velocity and a phase shift occurs between them. If the thickness of the material is such that it introduces a 90° phase shift between x and y components then this is referred to as quarter wave plate and the light comes out to be circularly polarized. If the thickness of the material is such that it introduces a 180° phase shift between x and y components then this is referred to as half wave plate and the light comes out to be circularly polarized.

Polaroids

There are certain types of crystals in which the refractive index as well as the coefficient of absorption is different for light polarized in different directions. Tourmaline and Polaroids are two major examples of such substances. Polaroids consists of a thin layer of small crystals of a salt of iodine and quinine aligned with their axis parallel the property of this salt is that is absorbs light is when the oscillations are in one direction and do not absorbs light when the oscillations are perpendicular. The emergent light will also lose half of its intensity. The resulting light wave is the polarized light. Polaroid filters fall under a group of materials commonly referred to as dichroic materials.

The reason for a Polaroid to be capable of polarizing light is the result of the chemical composition of the filter material. The filter can be considered to be composed of long-chain molecules which are aligned in the same direction. During the filter manufacturing process, the long-chain molecules are stretched across to ensure that each molecule is aligned in one direction. The direction of molecule alignment becomes the optic axis for the system.

Polarization by reflection

Un-polarized light can also be made polarized by reflection off suitable substances like metallic surfaces. The degree to which polarization occurs is dependent upon the angle of incidence of the light that approaches the surface and upon the material that the surface is made up of. Metallic surfaces have a peculiar property of reflecting light with a variety of vibrational directions; such reflected light is unpolarized. However, some non-metallic surfaces like asphalt roadways, snowfields and water reflect light such that there is a large concentration of vibrations in a plane parallel to the reflecting surface. A person viewing objects by means of light reflected off of these non-metallic surfaces will often suffer a glare if the extent of polarization is large. Fishermen are familiar with this glare since it prevents them from viewing and catching fish that lie below the water. Reason being light reflected off a lake is partially polarized in a direction parallel to the water's surface. Use of glare-reducing sunglasses with the proper polarization axis allows for the blocking of this partially polarized light, thereby reducing and the fisherman can more easily see fish under the water.

Polarisation by Refraction

Light waves can also be polarised by the method of refraction. Refraction occurs when a beam of light while travelling from one material into another, changes its direction at the surface of the two materials. The refracted beam acquires a certain amount of polarization. Generally the polarization occurs in a plane perpendicular to the surface of the two materials. The polarization of refracted light can be demonstrated in a Physics class using a unique crystal that serves as a double-refracting crystal, for example, Iceland Spar, a rather rare form of the mineral calcite, refracts incident light into two different paths. The light splits into two beams upon entering the crystal.

Polarization by Scattering

Light while travelling through a medium is scattered in various directions. It has been observed that this scattered light shows a certain amount of polarisation in a particular direction. As light beam strikes the atoms of a material it forces the electrons of those atoms to vibrate with the frequency equal to its own. As oscillating charge particles emit radiation, the vibrating electrons then produce their own electromagnetic wave that is radiated outward in all directions. This electron generated wave when strikes the neighbouring atoms, it forces the electrons into vibrations at the same original frequency. These vibrating electrons produce another electromagnetic wave that is once more radiated outward in all directions. This absorption and re-emission of light waves causes the light to be scattered about the medium. Peculiarity about this scattered light is that it is partially polarized. Polarization by scattering is observed at many natural phenomenons such as light passing through our atmosphere. The scattered light often produces a glare in the skies which is a measure of polarisation.

Applications of Polarization

Polarization has a multitude of applications in optical equipments of daily and of Astronomical importance, Spectroscopic apparatus etc. Some of the major industry as well as daily use of polarization is listed below:

1. Polaroid filters are used to differentiate longitudinal and transverse wave. As light passes through a plastic, each colour of visible light is polarized with its own orientation.

2. Polaroid filters are mounted on sun glasses to reduce unwanted reflected light.

3. Polarization microscopes were used to differentiate between different types of minerals.

4. Polarization plays a very important role in chemistry as in checking the chirality of the organic compounds. Infrared spectroscopy is also based on the principle of polarization.

5. Astronomical equipments based on polarization are being employed to study the Cosmic Microwave Background Radiation. Study of Cosmic Microwave Background Radiation is considered to be helpful in providing us information about the genesis of the universe. Also polarization techniques such as Faraday rotation are used for providing information on sources of radiation and scattering

6. While driving, the light reflected from the surface of the road and from the painted or glass surface of other automobiles is made to be partially polarized, usually horizontally, with the help of special antiglare Polaroid filters

7. The 3D effects in a movie are brought about by using multiplexed polarization techniques instead of projecting the image for each eye from two different projectors oriented

orthogonally. 3D glasses are provided with suitable filters to ensure that each eye receives only the intended image.

8. *Radar uses* intrinsically polarized light for all radio transmitting and receiving purposes. Vertical polarization is most frequently used when one has to radiate a radio signal in all directions such as in telecommunication.

9. The phenomenon of strain and birefringence are very intimately related hence justifying the use of polarization in analysing the distribution of stress and strain in materials.

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