A COMPREHENSIVE STUDY OF OPTICS

Gagan deep Kaur
Former Lecturer of Physics
Guru Nanak Polytechnic College, Damkora Road, Tohan

Abatract: Optics' practical applications are found in so much variety of technologies and everyday objects, including mirrors, lenses, telescopes, microscopes, lasers, and fibre optics.

Optics in the Greek philosophy divided into two opposing theories on how vision worked, and the intromission theory and the emission theory. The approach of intromission saw vision as objects casting off copies of themselves that were captured especially by the eye.

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Optics is one of the well-known branch of physics that mainly focus on the behaviour and properties of light, which in itself includes interactions with the matter and the construction of the instruments that use it. It is usually known as the behaviour of visible, ultraviolet, and infrared light. Light is an electromagnetic wave, and the other forms of electromagnetic radiation are X-rays, microwaves, and radio waves consisting the similar properties. The major portion of the optical phenomena can be used for the classical electromagnetic description of light. The complete and comprehensive descriptions of light are very much there, but these often difficult to apply in practical frame work. The practical optics is usually completed by using simplified models of its own kind. These are such as geometric optics, treats light as a collection of rays that travel in straight lines and bend when they pass through or reflect from surface. The physical optics is one of the more comprehensive model of light, which in itself includes wave effects such as diffraction and interference optics. As to discuss it from the historical point of view the ray-based model of light was first to be developed, and it was followed by the wave model of light. Electromagnetic theory's progress in the 19th century led to the invention of light waves those were in fact electromagnetic radiation. The phenomena depends on the fact that light has both properties such as wave-like and particle-like. The more comprehensive explanation of these effects also requires in the study of quantum mechanics. It is notable to consider light's particle-like properties, and the light is labelled as a collection of particles called "photons". The study of quantum optics deals with the application of the quantum mechanics to the optical systems. In this manner optical science is very much relevant to and it is also studied in many of the related disciplines including astronomy, various engineering fields, photography, and medicine. Optics' practical applications are found in so much variety of technologies and everyday objects, including mirrors, lenses, telescopes, microscopes, lasers, and fibre optics.

The notion of optics started with the development of lenses by the masses of ancient Egyptians and Mesopotamians. The earliest developed lenses were known and made from polished crystal, often quartz, and date from as early as 700 BC for Assyrian lenses such as the Layard/Nimrud lens. These practical developments in this process were followed by the development theories of light and the vision by Greek and Indian philosophers, and the development of geometrical optics in the Greco-Roman world was a new kind of revolution in this field. Optics is the word that has come from the ancient Greek word (optikē), meaning "appearance, look". Optics in the Greek philosophy divided into two opposing theories on how vision worked, and the intromission theory and the emission theory. The approach of intromission saw vision as objects casting off copies of themselves that were captured especially by the eye. With many propagators including Democritus, Epicurus, Aristotle and their followers, this theory seems to have some contact with modern theories of what vision really is, but it remained only speculation lacking any experimental foundation. Plato was the first who articulated the emission theory, the idea that visual perception is accomplished by rays emitted by the eyes. Some hundred years later, Euclid wrote a treatise entitled Optics where he tried to link vision to geometry, creating geometrical optics. The base of his work was on Plato's emission theory wherein he has described the mathematical rules of perspective and described the effects of refraction qualitatively, although he questioned that a beam of the light from the eye could instantaneously light up the stars every time someone blinked. Ptolemy on optics, held an extra mission-intromission theory of vision: the rays from the eye formed a cone like shape, the vertex being within the eye, and the base defining the visual field. The rays were very much sensitive, and conveyed the information back to the observer's intellect about the orientation of surfaces from distance. Euclid's much of ideas were briefed and went on to describe a way to measure the angle of refraction, though he was completely failed to notice the empirical relationship between it and the angle of incidence.

17th century was the period where Johannes Kepler expanded on geometric optics in his writings, covering lenses, reflection by flat and curved mirrors, the principles of pinhole cameras, inverse-square law governing the intensity of light, and the optical explanations of astronomical phenomena such as lunar and solar eclipses and astronomical parallax. He was also able to deduce the role of the retina as the actual organ that recorded images, finally being able to scientifically quantify the effects of different types of lenses that spectacle makers had been observing from more than 300 years. After the discovery of the telescope, Kepler made a theoretical basis on how they worked and described an improved version, known as the Keplerian telescope, using two convex lenses to produce higher magnification. With the progress of optical theory in the mid-17th century with treatises written by philosopher René Descartes, who explained a variety of optical phenomena including reflection and refraction by assuming that light was emitted by objects that produced it. This is indeed a different substantively from the ancient Greek emission theory. In the late 1660s and early 1670s, Isaac Newton elaborated Descartes' ideas into a corpuscle theory of light, which was famously determining that white light was a mix of colours which can be separated into its component parts within a prism. Christiaan Huygens in the year 1690 proposed a wave theory for light based on suggestions that had been made by Robert Hooke in 1664. He publicly criticised Newton's theories of light and the feud between the two lasted until Hooke's death. Newton in the year of 1704 published Opticks and because of his success in other areas of physics, he was called as the victor in the debate over the nature of light. The idea of optics that given by Newton was generally accepted until the early 19th century till the period Thomas Young and Augustin-Jean Fresnel conducted experiments on the interference of light that firmly established light's wave nature. Young's famous double experiment showed that light followed the law of superposition, which is a wave-like property not predicted by Newton's corpuscle theory. This theory of diffraction for light opened an entire area of study in physical optics. With the successfully unification of optics with electromagnetic theory by James Clerk Maxwell in the 1860s. Further development in the field of optical theory came in 1899 when Max Planck correctly modelled blackbody radiation by assuming that the exchange of energy between light and matter only occurred in discrete amounts he called quanta. Albert Einstein in the year 1905 published the theory of the photoelectric effect that firmly established the quantization of light itself. Niels Bohr in his research of 1913 showed that atoms could only emit discrete amounts of energy, thus explaining the discrete lines seen in emission and absorption spectra. The interaction between light and matter that followed from these developments not only formed the basis of quantum optics but also was crucial for the development of quantum mechanics as a whole in this field. The ultimate culmination, the theory of quantum electrodynamics, explains all optics and electromagnetic processes in general as the result of the exchange of real and virtual photons. The practical importance of Quantum optics with the inventions of the maser in 1953 and of the laser in 1960. The following progress and interdisciplinary nature of nanoscience and nanotechnology have made plasmonics one of the most exciting areas of research in the present times. Reducing the size of the element down to the nano-meter scale is very difficult by using conventional photonic devices due to Abbe`s diffraction limit. This limit can be overcome by the excitation of surface of the plasmons. Surface plasmons are electromagnetic excitation existing at metal-dielectric interface. Surface plasmons also provide the control and manipulation of propagation and dispersion of light on nano-meter scale. The first observation of plasmon resonance phenomenon was reported in 1902 by Wood. Zenneck in the year 1907 reported surface wave solution to Maxwell's equations and theoretically showed the occurrence of electromagnetic waves at the boundary of two media, one of which is in loss and other one loss free. Sommerfeld was able to establish the fact that field amplitudes of surface waves bear inverse relationship with the square root of horizontal distance from the source dipole. Fano's theoretical work on excitation of electromagnetic surface waves on the surface of the diffraction grating. In 1957 Ritche theoretically reported surface plasma oscillations at a metal surface. Turbadar in the year 1958 observed a large drop in reflected light intensity when illuminating thin metallic film on a substrate without linking this effect to surface plasmons. Powell and Swan reported an observation on excitation of surface plasmons at metal surfaces using electrons followed by the demonstration of electromagnetic surface waves at metal surface by Stern and Ferrell. Otto in 1968 demonstrated the drop in reflected light intensity in the attenuated total reflection (ATR) mode and reasoned this drop to be due to the excitation of surface Plasmons. It was also noted by Kretschmann and Raether that excitation of surface plasmons using another configuration of the attenuated total internal reflection method. These are reported pioneering works on surface plasmons introduced usefulness of plasmonics to modern optics. This was established that the propagation constant of a surface plasmon wave is very sensitive to the variation of refractive index of dielectric material next to the metallic film and this feature of surface plasmons can be utilized for optical sensing purpose. This aspect known as the sensing aspect of surface plasmon resonance was first demonstrated by Liedberg and Nylander. Multilayer prism based optical sensors for high precision chemical sensing was developed by Matsubara. The complete and comparative theoretical analysis for comparison of sensitivity between prism coupler and grating coupler employed in plasmonic sensors as well as an extensive review on surface plasmon resonance sensors were reported by Homola. The overall performance of a plasmonic sensor mainly depends on its design parameters. Theoretical and experimental analysis were carried out to observe the effect of different prism materials on performance of the designed sensor. Abeles matrices method's a detail numerical analysis based on for wave propagation in isotropic stratified media was carried out to find the distribution of electromagnetic field intensity within various layers of the multilayer plasmonic structure. Introduction of fiber optic technology in the field of surface plasmon resonance based sensing has made lot of advancements possible from sensor design and performance point of view. A detail review on features and aspects of fiber optic based plasmonic sensing was reported in. Comparative analysis between fiber optic plasmonic sensor comprising of step arrangement of thin metal layers of silver and gold and another fiber optic plasmonic sensor consisting of silver-gold bimetallic alloy layer was carried out. Metal nanoparticle based plasmonic sensors are preferred over conventional plasmonic sensors due to their ability to provide an extra degree of freedom for better sensing performance. A complete and concise review on various design configurations of optical fiber based plasmonic sensors for enhancement of sensitivity factor has been reported. The different types of Modeling techniques for plasmonic sensors were reviewed and the various categorized based on their optical structures and sensing performances. It was reported by Micheletto on sensitivity improvement using high refractive index substrate for surface plasmon sensing. Design and performance analysis of Kretschmann type nano-plasmonic sensor comprising of ceramic and chalcogenide materials using admittance loci method was carried out. High refractive index, wide transmission range, ability to produce narrower resonance curves and wider coupling configuration possibilities made chalcogenide glass as one of the exciting coupling prism materials. The potential of chalcogenide glass as a coupling prism material has been investigated theoretically and experimentally with eminent efforts. A highly sensitive and accurate aluminium metal film based plasmonic sensor comprising of chalcogenide prism material and working in infrared has been proposed. In a plasmonic biosensor graphene layer is used for enhancing the adsorption of biomolecules, which effectively increases the sensitivity, whereas use of chalcogenide material enhances the detection accuracy of the sensor. The overall performance of a chalcogenide prism is completely relied on the plasmonic broad range affinity biosensor using graphene multilayer and gold as a plasmon active metal was also investigated. Surface plasmon excitation in infrared light provides extra scope of using advanced light coupling materials, which enables sensor miniaturization and integration as well as improves sensor performance. Comparative theoretical and experimental analysis between silicon prism based plasmonic sensor and silica glass based sensor has been carried out by Patskovsky. Plasmonic sensing performance using silicon as a coupling prism material in infrared light was also reported by them. Possibilities and opportunities of an efficient plasmonic sensor comprising of silicon substrate and aluminium-gold bimetal for aqueous and gaseous sample detection operating under angular interrogation mode in infrared light has been discussed in. The behaviour of surface plasmons in infrared light is highly dependent on dispersion features of light coupling substrate material. Comparative study between chalcogenide and silicon as light coupling materials for plasmonic based chemical and gaseous sensing was carried over a wide range of infrared wavelengths. Admittance loci based detail theoretical investigations were carried out for designing plasmonic sensors comprising of silicon, chalcogenide and silica as light coupling materials in infrared light. Performances of different plasmon active metals using prism based and optical fiber based plasmonic structures have been investigated. Influence of different bimetallic nanoparticle alloy film combinations on the performance of fiber optic plasmonic sensors using fused silica as light coupling fiber core material have been theoretically investigated and demonstrated by Sharma. Performance of silver-gold bimetallic alloy film based plasmonic sensor comprising of chalcogenide prism material in infrared light was investigated in terms of alloy fraction and nanoparticle sizes showing improvement in sensing. A comprehensive theoretical study between a gold metal-host based fiber optic plasmonic sensor and silver-gold bimetallic alloy film based fiber optic plasmonic sensor was carried out in terms of signal-to-noise ratio and sensitivity parameters. Modeling and performance analysis of a prism based plasmonic structure comprising of silver-gold bimetallic alloy film in terms of alloy fraction values and nanoparticle sizes using admittance loci method have been reported by us. Works on nano-composite film based surface plasmon resonance based gas sensors have been demonstrated. Admittance loci method is a well-known technique using which a multilayer thin film structure can be built. Studies on novel design of plasmonic sensing device comprising of alternate dielectric layers for enhancing the surface plasmon signal quality and modulating its resonance dip position using admittance loci method have been reported by Lin. Admittance loci based design of prism coupling configuration for propagation of long-range surface-plasmon-polariton (LRSPP) waves of all polarizations was presented in. In addition, normalized admittance diagram was used in modeling multilayer thin film prism based plasmonic structures to excite longrange surface-plasmon-polariton (LRSPP) waves of either p-polarization or s-polarization states. Mechanism and design issues of p and s polarized ultra-long-range surface plasmon-polariton (SPP) propagation in a multilayer plasmonic structure comprising of prism, equivalent coupling layer (ECL), metal film and equivalent substrate were demonstrated using normalized admittance diagram. Arbitrarily polarized long-range surface-plasmon-polariton waves were discussed in the article. Admittance loci based analysis has also been carried out for modelling and analyzing the performance of multilayer plasmonic structures comprising of different prism materials and different chemical and biological samples. Besides the above-mentioned important literatures relevant to the present thesis, a wide range of books and review articles are available describing the principle advancements of the SPR technique and its applications in vast field of bio-sensing and nano photonic devices.

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