On the Nature of Light

by Ranbir Sharma - Friday, February 07, 2014

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It is the fastest in the universe and has to be fast since nothing can even reach its speed. Light or lux lucem more about numerous others that sustain life on earth. It is not just about the visible wavelengths but even

The scientific study of the behavior of light is called optics and covers reflection of light by a mirror or other objects, reflection by a lens or prism, diffraction of light as it passes by the edge of an opaque object, and interference patterns resulting from diffraction. Also studied is the polarization of light Any successful theory of the nature of light must be able to explain these and other optical phenomena.

The earliest scientific theories of the nature of light were proposed around the end of the 17th century. In 1690, Christian Huygens proposed a theory that explained light as a wave phenomenon. However, a rival theory was offered by Sir Isaac Newton. Newton, who had discovered the visible spectrum in 1666, held that light is composed of tiny particles, or corpuscles, emitted by luminous bodies. By combining this corpuscular theory with his laws of mechanics, he was able to explain many optical phenomena.

For more than 100 years, Newton's corpuscular theory of light was favored over the wave theory, partly because of Newton's great prestige and partly because not enough experimental evidence existed to provide an adequate basis of comparison between the two theories. Finally, important experiments were done on the diffraction and interference of light by Thomas Young (1801) and A. J. Fresnel (1814–15) that could only be interpreted in terms of the wave theory. The polarization of light was still another phenomenon that could only be explained by the wave theory. Thus, in the 19th century. the wave theory became the dominant theory of the nature of light.

The wave theory received additional support from the electromagnetic theory of James Clerk Maxwell (1864), who showed that electric and magnetic fields were propagated together and that their speed was identical with the speed of light. It thus became clear that visible light is a form of electromagnetic radiation, constituting only a small part of the electromagnetic spectrum. Maxwell's theory was confirmed experimentally with the discovery of radio waves by Heinrich Hertz in 1886. Two great revolutions in Physics, namely Quantum Mechanics and Relativity, bear there epochs in the heart of electrodynamics.

Quantum Mechanics once told us that light is absorbed and emitted in tiny discrete packets, known as photon. But it is not yet been settled that light is actually a steam of photon or not. Like in the case of water waves, (which obey the laws of reflection) which actually constitutes of water molecules, whose overall motion appears as waves, in the same rhythm, we can say that ‘a light beam delivers so many minute quanta that its inherent granular nature is totally hidden and a continuous phenomenon is observed macroscopically’. But there are still unsettled arguments in this belief.In 1900 Planck took the first step towards quantum mechanics by explaining the black body radiation problem in which he assumed that the oscillators(which are actually atoms or molecules in the black body chamber that emits and absorbs radiation)) are quantized (i.e. absorbed or emitted discrete amount of energy), not the EM wave itself.

The modern concept of EM radiation came up as the explanation of the Photoelectric effect, given by Albert Einstein in 1905. When a metal is exposed in the EM radiation it emits electron, which is called as

Photoelectric effect. Einstein argued that if the source of EM wave can emit and absorbed energy in discrete packet why not the whole EM waveform. The electromagnetic field should exist as discrete energy packet. Each packet bears all the characteristic of the EM wave. These packets are the quantum of light which we call as Photon. 'Photon are stable, charge-less mass-less elementary particles that only exist at the speed of light'.In the Maxwell theory of Electrodynamics we get that the speed of light is c (299792458 m/sec). We always describe the motion of matter with respect to a frame, so naturally the question come, 'with respect to which frame we calculate this speed of light?' So we need an absolute frame of reference in which the Maxwell laws of Electrodynamics were formulated. This was the time when the concept of luminiferous ether was emerged, as the absolute frame of reference. If this is true that there exists a medium known as ether through which EM radiations propagates and which exists everywhere, with respect to which we formulate all our physical laws then speed of light should vary from frame to frame. But all the experiment carried away to determine the speed of light, considering different frame of reference, give the same value, 299792458 m/sec. So the ether concept increase the complexity of the problem. Einstein solved this problem by reformulate the laws of Mechanics leaving the Maxwell Electrodynamics intake, by postulating that 'Speed of Light in All the Frames are same'. The emission or absorption of EM radiation is independent of speed of the emitter or absorber, so the speed of light should be same everywhere. This postulate make us to consider Lorentz transformation in spite of Galilean transformation when we transform our physical quantity from one inertial frame to other. This postulate also input some new concept in the realm of physics, such as length contraction, time dilation, mass to energy transformation and vice-versa. Special theory asserts that there should not be any absolute frame, and hence time measurement may vary from person to person. Special theory of relativity is a kind of unification between mechanics and Electrodynamics, and it open up the hidden book of space and time.

Let us come back to Black body Radiation. In 1924 the Indian physicist S. N. Bose formulated a technique to solve the problem of black body radiation, in a more rigorous manner, by considering that the chamber of black body is filled up with a 'gas' of photon. He considered each photon particles to be indistinguishable from each other. That means we can exchange one photon particle with another one. His statistical technique is popularly known as Bose –Einstein statistics, which is greatly differ from the classical statistical technique.

Photoelectric effect and black body radiation, are the points from which quantum mechanics evolved. From Bose statistical formulation, photon becomes an indispensable part of theoretical physics.

We know that every classical wave propagate through a field or a medium. Electromagnetic waves in the other side move in electromagnetic field which is created by the wave itself, which means that for propagation of electromagnetic wave there should not be any static field, which we can 'see' after and before the passing of the wave. A EM wave propagate through empty space by consecutive creation of electric and magnetic field, the changing electric field produces the changing magnetic field and vice versa.

The interpretation of the nature of light developed continually by the evolution of quantum mechanics. Quantum Field Theory, which deals with the nature of micro-particle and their interaction, is the most fundamental and a most successful theory. Concept of quanta of light comes out naturally from this theory, as the quantization of EM field. QFT suggests that all particles comes up as the quantization of their fields, viz- electron comes up as the field particle of electron field, neutron comes up as the field

particle of the neutron field.

There are two philosophical currents in contemporary QFT, field-centered and particle centered view. ‘In the field centered view the fundamental entities are the fields and particles are just the quanta of fields, again in particle centered view, particles are the fundamental entities and fields are just the macroscopic coherent states of particles’. The relativistic quantum field theory of electrodynamics is called Quantum Electrodynamics, which is developed greatly by R. P. Feynman. According to him “light is made up of particles (as Newton originally thought)”, whose macroscopic behavior can be determined statistically or by the application of the postulates of quantum mechanics. This is the particle centered view, there exist also the field centered aspect of QED.

The evolution of the concept of nature of light, is an exciting and adventurous path, which illuminate many secrets of space and time. As Einstein said one can spend his whole life happily in search of the nature of light.

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