

Interpretation of Physics related with Light

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Abstract

Ampere-Maxwell equation can predict the speed of light by assuming light as a traveling wave. However, it can not predict such characteristics as light generation, moving in a specific direction as a particle and dependence of wavelength upon its energy. Therefore, it needs to be noted that Ampere-Maxwell equation is very limited in predicting characteristics of light. While physics law should be applied to all the inertial frames, co-variance that mathematical form of the equation describing the physics law is same in all the inertial frames is not essential requirement to be physics law. Therefore, Lorentz transformation to result in both the co-variance of Ampere-Maxwell equation for light and the constant velocity of light in all the inertial frames is not the essential requirement. Considering light as a discrete particle with wave characteristics inside, analysis of double slit experiment indicates that travel direction of each photon after slit would be decided at the slit by interaction of incident photon with the slit including its materials and geometry to result in the interference pattern at the screen. There is no direct evidence of occurrence of superposition of photon in the slit and interference of the photon at the screen to result in the interference pattern. If there is no superposition of photon, quantum mechanics and entanglement of photon related with photon superposition need to be updated.

Keywords : Light, Maxwell Equation, Special Theory of Relativity, Lorentz Transformation, Double Slit Experiment, Interference, Superposition, Entanglement

1. Introduction

Light can be generated by vibration of an electron in an exciton in LED(light-emitting diode) bulb. After generation, light travels at the specific speed in a fixed direction from its source[1]. Interpretation of such characteristics of light as generation and interaction with the matter showed that light is a discrete one or a particle [1, 2]. Inside a particle of light, there exists a characteristic of wave with oscillating electric field and oscillating magnetic field induced by oscillating electric field. While the speed of light is constant, its velocity depends upon movement of its source following Newtonian mechanics of motion as same as normal object [2]. Speed is magnitude of velocity while velocity is a vector with both magnitude and direction.

Therefore, the conventional postulates on light such that light is generated in the source as a wave and travels into the space spherically uniformly, and velocity of light is constant in all the inertial frames independent of movement of light source are not correct [2].

Based upon these understanding on light, some of physics related with light are to be updated as follows.

2. Maxwell Equations for Light

James Clerk Maxwell consolidated the electricity and the magnetism into four equations as follows[3].

- Gauss's law of electricity such that electric field is generated by electric charge.
- Gauss's law for magnetism such that magnetic field lines are continuous and circulating.
- Faraday's law of induction such that changing magnetic field generates electric field which can force electric charge to move to make electric current.
- Ampere-Maxwell law such that a circulating magnetic field is generated by both the electric current and the changing electric field.

Ampere law is that an electric current generates a magnetic field. J. Maxwell added the term to Ampere's law that a changing electric field can generate a magnetic field. It is kind of extension of Ampere's law that movement of electric charge induces the magnetic field. Then, Ampere-Maxwell equation becomes as follows.

$$\nabla \times \mathbf{B} = \mu_0 (\mathbf{J} + \epsilon_0 \partial \mathbf{E} / \partial t)$$

where,

\mathbf{B} = the magnetic field

$\nabla \times \mathbf{B}$ = the curl of magnetic field, \mathbf{B}

μ_0 = the permeability of free space

\mathbf{J} = the current density from moving charges

ϵ_0 = the permittivity of free space

\mathbf{E} = the electric field

$\epsilon_0 \partial \mathbf{E} / \partial t$ = the displacement current density from a changing electric field

The term added by J. Maxwell has indicated the existence of electromagnetic wave. It resulted in the

prediction that light travels at the specific speed of light as an electromagnetic wave with both oscillating electric and magnetic fields.

However, it needs to be noted that Maxwell equation can not predict such other characteristics of light as its generation, a particle with wave characteristic inside, specific direction of light traveling after generation, dependence of wavelength or frequency of light upon its energy, and polarization of light depending upon direction of oscillation of electric and magnetic fields inside light. Since Ampere-Maxwell equation can predict only the speed of light by assuming that light travels as a wave, Ampere-Maxwell equation is very limited in predicting the whole characteristics of light.

Physics laws should be applied to all the inertial frames. Inertial frame is defined as a frame which moves at constant velocity without any acceleration. The frame where we stand still is an inertial frame. When we ride a train moving at constant velocity, both we and train are in the same inertial frame. In those two different inertial frames, Newtonian mechanics of motion on movement of objects can be applied independently. The same form of equation of Newtonian mechanics of motion can be applied to all the inertial frames.

Co-variance is defined such that mathematical equation of physics law is maintained in the same form in all the inertial frames. Newtonian mechanics of motion satisfies the co-variance. However, co-variance can not be applied to the phenomenon of physics with the parameter which varies depending on the specific location in a specific frame such as normal wave in the string, heat transfer and diffusion. Those phenomena are not independent of the inertial frame. Only when variation of a parameter is independent of the location, co-variance is satisfied.

Therefore, while physics law should be applied to all the inertial frames, co-variance that mathematical form of equation describing the physics law is same in all the inertial frames is not essential requirement or not the necessary and sufficient condition to be physics law.

Special theory of relativity proposed by A. Einstein is based upon two postulates[4]. First is that the law of physics is applied to all the inertial frames. Second is that the velocity of light is constant in vacuum independent of the inertial frames, that is, independent of movement of light source.

When Lorentz transformation is applied to the Ampere-Maxwell equation for light, same mathematical form of the equation is maintained in all the inertial frames as well as satisfying the second postulate that light velocity is constant in all the inertial frames. However, application of Lorentz transformation to two different inertial frames such as the stationary frame and the frame moving with constant velocity leads to the results that length is shortened in moving frame and time passes slowly in moving frame, compared with the stationary frame, which can not be accepted intuitively with common sense. As the velocity is the function of only two variables such as length and time, Lorentz transformation is kind of adjustment of them.

When Special theory of relativity that velocity of light is constant independent of movement of light source is applied, Radar Paradox occurs as follows. When two objects of A and B approaching each other emit the light of radio wave toward each other at the same time, the one which is considered as moving with velocity(v) toward to the other at stationary is always hit earlier by the radio wave than the one at stationary since velocity of radio wave is assumed constant independent of movement of radio wave source in Special theory of relativity [2]. Since in relative motion, any object can be assumed to be moving toward the other, any object can be hit first by just that assumption [2]. Therefore, it is paradox, called as Radar Paradox.

Considering both the limited capability of Ampere-Maxwell equation and the fact that same form of mathematical equation, that is, co-variance in all the inertial frames is not the necessary and sufficient condition to be physics law, application of Lorentz transformation to Maxwell equation is not required or not necessary. Second postulate in Special theory of relativity that the velocity of light is constant in vacuum independent of inertial frames, that is, independent of movement of light source is the postulate which is not based upon any observation or experiment. Therefore, Special theory of relativity on light is not required and not correct[2].

3. Relation of Electricity and Magnetism

The word of electron was named by William Gilbert based upon Greek word, the amber showing the static electricity. Magnet is named after the province of Magnesia in Greece where natural rock of magnet was found. In 1864, J. Maxwell wrote that “the theory I propose may therefore be called a theory of electromagnetic field, because it has to do with the space in the neighborhood of electric or magnetic bodies” [5]. The words such as electromagnetic, electromagnetic wave and electromagnetism were derived based upon it. According to Ampere-Maxwell equation, light was conceived as a wave with oscillating electric and

magnetic fields, so that light was called as an electromagnetic wave.

Electron, electricity, electric field and magnetic fields can be measured. However, electromagnetic field can not be measured directly. As light has a characteristics of a wave with oscillating electric and magnetic fields, electromagnetic field is conceived to be in light without direct measurement.

Maxwell's equations can predict the effect of change of electric and magnetic field upon electricity and magnetism. Vibration or acceleration of electron can generate photon. Inside the photon, there is oscillation of both the electric and the magnetic fields. According to Ampere's law, variation of electric field induces the magnetic field, and it can be applied to a photon to be an electromagnetic wave.

The magnetic field generated by a magnet is induced by vibration of electrons in the atoms of the magnet. It means that change of electric field by movement of electrons in atoms in the magnet induces magnetic field of the magnet. Therefore, it can be said that electric field is primary and magnetic field is secondary.

When two magnets approach each other with same magnet pole of N or S, two magnets are repulsive to each other before contact due to the same magnetic field. It is same such that two charged particles with same charge are repulsive to each other before contact. There exists a force caused by magnetic or electric field. It shows that the force between fields of the magnetic or the electric of the objects can push the objects without physical contact. Photo-electric effect is that photon can eject electron in an atom by interaction. This photo-electric effect may be caused by interaction of electric fields of both the photon and the electron in an atom.

Let's assume that a free electron is moving into the space with static magnetic field. It can be analyzed as the two different cases. Case A is that free electron moves with velocity(v) into the space with static magnetic field which varies with location. Case B is that the space with the magnetic field which varies with location is moving to the static electron which generates the electric field varying with distance from its electric charge. Cases A and B are same in terms of classical Galilean principle of relativity.

For Case A, moving free electron gets the Lorentz force depending upon its velocity and external magnetic field(B), and then the electron is deflected due to Lorentz force(F) as follows.

$$F = q (E + v \times B) = q (v \times B), \text{ since } E = 0$$

For Case B, static electron interacts with changing magnetic field as follows.

$$\nabla \times E' = - \partial B' / \partial t$$

Changing magnetic field ($\partial B' / \partial t$) generates electric field (E') according to Faraday's law. Then, static electron with charge(q) gets the force from the generated electric field(E') according to Coulomb's law as follows.

$$E' = (v \times B)$$

$$F' = qE' = q(v \times B)$$

Then, the forces of cases of A and B are same as follows.

$$F = q (v \times B)$$

$$F' = q(v \times B)$$

Therefore, it shows that classical Galilean principle of relativity is valid in Maxwell equations in the interaction between an electron and magnetic field. Accordingly, Lorentz transformation is not necessary in the Maxwell equations to predict relative interaction of an electron and magnetic field. In this simple case of an electron and magnetic field, there is no asymmetry which A. Einstein raised in the case of conductor and magnet in his paper of "On the electrodynamics of moving body" in 1905[4]. As there are much more electrons and positive nuclei in conductor, electric fields are much more complex than that of a single electron.

4. Analysis of Double Slit Experiment

Double slit experiment showed the pattern of repetition of bright and dark regions from brighter region in center. Since Thomas Young's first experiment in 1801, double slit experiments have been extensively investigated to study the characteristics of light [6, 7]. Discussion on whether light is a particle or a wave has also been continued extensively.

In 19th century, wave theory of light has prevailed following interpretation of Thomas Young on the results

of double slit experiment. Results of double slit experiment was quite similar to the phenomenon such that when water waves are passing through two adjacent openings, the interference pattern is formed continuously as they spread out. Ampere-Maxwell equation successfully predicted the speed of light by assuming light as a wave.

Then, A. Einstein explained the photoelectric effect by assuming a discrete energy of light in 1905 such that electron in atom can be ejected after collision with light. It indicates the particle characteristic of light which I. Newton proposed before. As the light shows characteristic of wave in double slit experiment and characteristic of particle in photoelectric effect separately, duality of particle and wave was proposed to define light as kind of the compromise, which is somewhat ambiguous.

Conventional interpretation of double slit experiment is as follows[3, 7]. The concept of superposition, and self interference of a photon or interference of different photons were used to explain the interference pattern at the screen in double slit experiment. Superposition of photon is defined such that a photon can exist in multiple states in position, polarization and even energy at the same time. Self interference of a photon is defined such that a photon is divided into two or more by superposition and then be combined again to result in constructive or destructive interference depending upon phase difference. Interference of different photons is that photon interferes as wave with other photons to make constructive or destructive interference depending upon their phase difference when they meet.

Therefore, as a single photon passes through the slit or slits, a photon is divided two or more different states by superposition process. Then, superposed photon arrives at the screen to interfere with other superposed photon to result in the pattern of bright and dark in the screen, called self interference. Therefore, interference pattern in the screen is result of superposition of photon made by interaction with slit followed by self interference of the superposed photon at the screen. The concept of superposition of photon and self interference are difficult to understand with common sense.

Based upon the finding[1, 2] that light is a discrete one or a particle with the wave characteristics of oscillating electric and magnetic fields inside, double slit experiment can be analyzed as follows.

Since interaction of light in the double slit experiment is more complex, it would be better to start with a

single slit experiment. Airy disk is an experiment with a hole[8]. Hole plays the role of slit. It shows pattern of circular bright and dark area starting from central brighter circle. Therefore, single slit experiment also shows the interference pattern as same as that of double slit experiment. However, analogy of water waves from two holes which was applied to double slit experiment can not be applied to single slit experiment. Therefore, there should be some other way to explain both double and single slit experiment together.

Results of single slit experiment like Airy disk can be interpreted as follows. Incident photon interacts with the slit. Then, travel direction of photon coming out of slit is decided by interaction of incident photon and slit depending upon slit geometry and slit materials. Variables of incident photon are its approaching angle to the slit, its energy and direction of polarization. The variables of slit are slit geometry such as width and distance between slits, and slit material such as atoms and electrons and their electromagnetic environment, which can influence the photon for passing, diffraction, reflection, refraction, absorption and re-emission.

Some photons can interact with edge of slit to be diffracted or reflected. Some photons could directly pass through the slit without significant interaction with slit. There are lots of possibilities for diverse interactions between photons and slit to generate the pattern at the screen. In the case that cross section of photon beam is larger than slit size, interaction of photons with slit surface could influence the electromagnetic environment of slit to affect photons passing through the slit.

Since there is no matter like void between slit and screen, it would be reasonable to assume that the pattern at the screen was already decided at the slit. Considering the particle characteristics of light, this interpretation could be more reasonable than the conventional interpretation that superposition of photon occurs at the slit and self interference of the superposed photon occurs at the screen.

Results of double slit experiment by a using single photon showed that each photon arrives probabilistically at the screen and then accumulation of those photons results in the interference pattern at the screen [9]. It would be reasonable to recognize that result of double slit experiment using light beams of many photons would be same as that accumulated by a single photon experiment. S. Putt et al[10] performed the experiments to investigate how light travels in both double and single slit experiments. The results showed directly that travel direction of light was decided in slit and then light travels in straight direction to form the interference pattern at the screen. It also showed that the reflected light from the slit makes the same

interference pattern as that of the light which passed the slit.

Superposition of photon is that a photon can exist in multiple possible states at the same time such as position, polarization and even energy. It can not be measured directly for verification, and also difficult to imagine. And, if there is no superposition, there is no self interference.

Considering that a photon travels very fast at the speed of light, and a photon is a particle having characteristic of wave inside which is electric and magnetic fields oscillating in specific direction depending upon its polarization with individual frequency, it would be very difficult that interaction of photon with other photon as wave to make constructive and destructive wave to show the interference pattern at the screen in the slit experiment. Therefore, interference of a photon with other photons would be very unlikely.

Therefore, it would be more reasonable to acknowledge that the interference pattern at the screen was decided at the slit by interaction of incident photon with slit of geometry and materials in both single and double slit experiments. There are no clear evidence to support existence of the phenomena such as the superposition of photon, self interference of the superposed photon, and the interference of the separate photons.

Quantum is defined for the basic elementary particles such as proton, electron, photon and atom. Some of quantum mechanics is based upon assumption of superposition of photon. Therefore, if there is not superposition of photon, quantum mechanics on photon may need to be updated.

Entanglement of photons is that two or more photons are generated in a combined states of superposition. If a concept of superposition of photon is not valid, entanglement of photons may need to be updated by analysis of experimental results about entanglement of photon without using a concept of photon superposition.

Polarization of two photons generated in SPDC(Spontaneous Parametric Down Conversion) may have been decided at their generation at SPDC according to conservation of angular moment[1]. It may need to be considered that polarization of photon may be changed during its travel by interaction with the beam splitter, the filter to check the status of polarization of photon, and others which photon meets or penetrates during travel. Therefore, there may not exist any spooky interaction between two photons that were generated in

SPDC and were separated with long distance, which A. Einstein was concerned.

5. Summary and Conclusion

As it was found that light is a discrete one or a particle with wave characteristics inside, and its velocity depends upon movement of light source, some of physics related with light were analyzed.

While Ampere-Maxwell equation can predict the speed of light by assuming light as a traveling wave, it can not predict other characteristics of light such as its generation, a particle with wave characteristic inside, specific direction of light traveling after generation, dependence of wavelength or frequency of light upon its energy, and polarization of light depending upon direction of oscillation of electric and magnetic fields inside light. Therefore, Ampere-Maxwell equations are very limited in predicting whole characteristics of light.

Physics laws should be applied to all the inertial frames. However, co-variance that mathematical form of the equation describing the physics law is same in all the inertial frames is not essential requirement to be physics law. Therefore, Lorentz transformation to result in both the co-variance of Ampere-Maxwell equation for light and the constant velocity of light in all the inertial frames is not the essential requirement.

Results of double slit experiment was analyzed considering that light is a discrete particle with wave characteristic inside. Results of double slit experiment by using a single photon showed that each photon after passing slit is distributed probabilistically at the screen to form the interference pattern through accumulation of photons [9]. Experiment by S. Pütt et al showed that travel direction of photon could be decided at the slit and then photon travels in that fixed direction after passing the slit[10]. Those results indicate that travel direction of each photon after slit may be decided at the slit by interaction of incident photon with slit and its material to result in the pattern in the screen.

In the experiments of both the double slits and the single slit, there is no direct evidence of superposition of photon in the slit, self interference of the superposed photon, and interference of separate photons at the screen to result in interference pattern. Therefore, there may not exist the phenomena of superposition and self interference of photon.

If there does not exist superposition of photon, quantum mechanics and photon entanglement related with photon superposition need to be updated. Polarization of two photons generated in SPDC(Spontaneous Parametric Down Conversion) may have been decided at their generation according to conservation of angular moment. Therefore, there may not exist any spooky interaction between two photons that were generated in SPDC and were separated with long distance, which A. Einstein was concerned.

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