Dependence of Light Velocity upon Movement of Light Source

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Abstract

The special theory of relativity proposed by Albert Einstein in 1905 postulates that velocity of light is independent of movement of its light source. It is different from conventional Newtonian mechanics for objects. Based upon advancements in understanding light up to now since 1905, dependence of light velocity upon movement of its light source was investigated. Analysis of characteristics of light such as generation, traveling and interaction with the matter showed that light can be regarded as a discrete one, a particle or a photon. Through analysis of the results of the Michelson-Morley experiment and the working mechanism of radar, it was found that velocity of light depends upon velocity of the light source. Therefore, Newtonian mechanics can be applied to light as same as all the other objects. The evidences which have been used to support the special theory of relativity, such as light from binary stars and time dilation measured in satellite using atomic clock were discussed to show that they can not be solid or sufficient verification. The subjects which need to be updated when the special theory of relativity is not valid, were discussed. As Newtonian mechanics is applied to light, physics and the universe could be more easily conceivable and accessible by using the frame of the three-dimensional space and time.

***Keywords*:** Light, Special Theory of Relativity, Light Velocity, Light Generation, Michelson-Morley Experiment, Radar, Redshift of Light

1. Introduction

Light has been one of the most important elements in understanding physics and the universe including the surrounding environment, Earth, sun, galaxies and more. Albert Einstein in 1905 proposed the special theory of relativity postulating that velocity of light is independent of movement of its light source [1]. Since it is totally different from Newtonian mechanics of relative motion, it has been quite difficult to understand intuitively with common sense.

Since 1905, there has been much advancement in understanding the characteristics of light. By taking into account the mechanism of light generation and the interaction of light with the matter, dependence of light velocity upon movement of its light source is to be analyzed.

2. Characteristics of Light

When visible light comes from candle fire, it is generated by vibration of the electrons in the heated gases such as carbon dioxide in the fire. Electron vibration caused by receiving the energy generated by carbon oxidation in the candle can induce electron in initial stable energy state to move up to higher energy level state, leaving the vacant space in that initial state. Then, when the electron returns to the initial lower energy state, light is generated with the energy of the difference between those two energy level states. A pair of an electron and a hole in the initial energy state is called an exciton. LED(light emitting diode) bulb uses this mechanism to generate light with a specific energy or wavelength by controlling the energy difference in two energy states in an exciton.

The electron in orbits of an atom or molecule has a self-rotating spin under a specific electromagnetic field of the atom or molecule. The traveling direction of the light generated in an exciton would be decided depending on those conditions of state of the electron in the atom or molecule. As there are so many electrons in the heated gases, which are in diverse states, light is detected by human eye to be emitted uniformly or isotopically in all directions. In reality, each light or photon is generated with a specific energy and emitted to a certain direction by vibration of an electron. Black body radiation emitted from the material of a specific temperature is a collection of the light generated by the population of electrons in the material that vibrate between diverse energy levels depending upon the temperature of the material. Since light is generated by vibration of an electron in exciton, light can be regarded as a discrete one, a particle or a photon.

After generation, light travels at high speed, about 300,000km/sec in vacuum, and can interact with the matter. Light travels like transverse wave with both electric and magnetic fields oscillating perpendicular to each other, transversely to the direction of travel. Therefore, light can be regarded as an electromagnetic wave. Considering both generation and traveling behavior of light, light can be understood as a discrete one with the characteristics of a transverse wave, and therefore, can be defined as a particle with wave characteristics, or a wave particle. The wavelength of light is inversely proportional to the energy of light. Depending on its wavelength, light is categorized as a radio wave, microwave, infrared light, visible light, ultraviolet light, X-ray or gamma ray as shown in Figure 1.

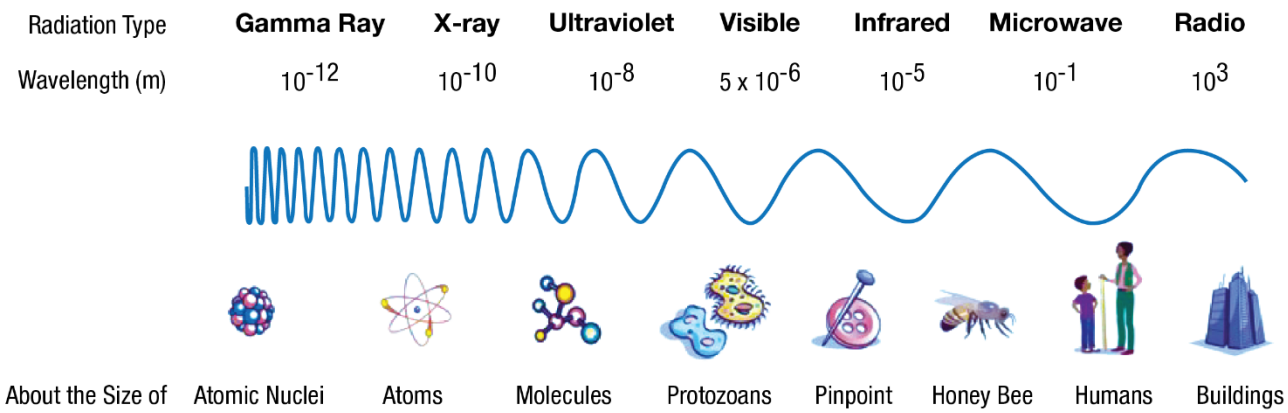

Figure 1. Spectrum of Light[2]

Light can interact with the matter including an electron, nucleus, atom, charged particle, molecule and other materials. These interactions lead to the phenomena such as reflection, absorption, refraction, diffraction and scattering. Light tends to interact more easily through resonance at the frequency with the matter where it was generated. Visible light generated by vibration of electrons in an atom tends to interact with electrons in atoms. When light interacts with an electron, it can collide with the electron elastically to change its direction of travel, or it can transfer a fraction or all of its energy to the electron. When the electron get the energy from light, it vibrates and can generate another secondary light by its vibration.

A mirror is coated with the materials which tends to reflect visible light by collision with electrons in the mirror. Transparent glass tends to pass visible light with a weak interaction with light. In glass, visible light interacts with the electromagnetic fields formed by the electrons in the glass. Interaction of light with electrons can result in a change of travel direction of light and energy transfer from light to electron resulting in subsequent generation of secondary light. Through these interactions, the speed of light in the glass decreases depending upon the wavelength of light.

When the amount of energy transfer from light, a single photon to an electron is sufficient, the electron can escape from the atom to become a free electron. It is called photoelectric effect which was found by H. Hertz and later explained by A. Einstein using the concept of a particle nature of light with a specific energy. Photovoltaic panels utilize this photoelectric effect to produce electricity by using the free electrons induced by sun light.

When a light receiver moves toward the light source, a receiver gets more energy than the original energy of light generated in the light source. It is called blue shift as blue color light has higher frequency or more energy. A receiver departing from a light source gets less energy, or lower frequency. It is called a red shift as red color light has lower energy or lower frequency. Therefore, light having characteristics of a transverse wave shows a Doppler effect as same as other waves such as sound wave, which is caused by relative motion of wave and receiver.

A gamma ray is light with very high energy as shown in Figure 1. It can be generated in a nucleus of an atom where vibration of electric charge occurs between the energy levels with a very high energy difference. When gamma ray of high energy approaches to interact with the nucleus, a pair of electron and positron can be generated. This shows that the energy of light can be converted to mass according to the relation of $E=mc^2$, which A. Einstein discovered. A positron can interact with an electron through annihilation to generate two gamma rays traveling in opposite directions. The annihilation of positron and electron pair shows that mass can be converted to an energy without mass, a gamma ray following the relation of $E=mc^2$. Mechanism of the interconversion of light and the electron having mass and electric charge is not yet fully known. Therefore, there is still very much left to be understood about light.

3. Dependence of Light Velocity on Movement of Light Source

3.1 Evaluation of Special Theory of Relativity

The status of understanding about light before 1905 can be summarized as follows. In the 19th century, after James Maxwell derived the electromagnetic equations integrating all the findings by Michael Faraday, A Ampere and J. Gauss. As Maxwell equation predicted the spped of light by assuming light as a wave, light was understood as an electromagnetic wave. Then, there seems to exist a consensus or an assumption that “light, as a wave such as a sound wave or tide may travel in a medium, called the aether, in the universe, independent of Earth’s movement”. It needs to be noted that there was no clear evidence to support this consensus or assumption.

In 1887, Michelson and Morley performed an experiment to examine the effect of Earth's movement on the velocity of light, as illustrated in Figure 2[3, 4, 5].

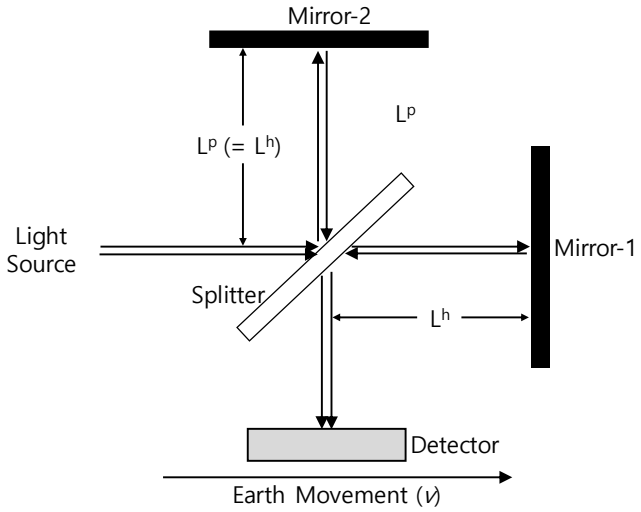

Figure 2. Schematics of the Michelson-Morley Experiment

It was expected that there would be differences in travel time of light between two directions due to Earth's movement in one direction. However, to the surprise of them, results of Michelson-Morley experiment showed that there was no difference in the travel times of light between two directions regardless of Earth's movement in one direction. To explain the results of Michelson-Morley experiment, Hendric Lorentz's mathematical coordinate transformation was derived to result in the concepts of time dilation and length contraction. Then, Albert Einstein proposed the Special theory of relativity in 1905. Mathematical analysis of the Michelson and Morley experiment based upon Special theory of relativity is as follows[4.5]

When light moves independent of Earth's movement, or independent of motion of the light source,

Travel time of light in horizontal direction(t_1) = $\frac{L^h}{c-v} + \frac{L^h}{c+v} = \frac{2L^h}{c}\beta^2$,

where, $\beta = (1 - \frac{v^2}{c^2})^{-1/2}$.

Travel time of light in perpendicular direction(t_2) = $\frac{2L^p}{c}\ (1 - \frac{v^2}{c^2})^{-1/2} = \frac{2L^p}{c}\beta$

Results of Michelson-Morley experiment showed that t_1 is equal to t_2. Then

$L^h = L^p\ \beta^{-1} = L^p\ (1 - \frac{v^2}{c^2})^{1/2}$.

Therefore, it is assumed that since L^h is less than L^p , length contraction has occurred in horizontal direction by the movement of Earth.

The special theory of relativity is consistent with Hendric Lorentz's transformation resulting in the concepts of time dilation and length contraction since both assume that velocity of light is constant independent of movement of its light source. That is, time elapses slowly in a moving object and length is reduced for a moving object.

The paper on the special theory of relativity published by A. Einstein in 1905 starts with the postulation that the velocity of light is constant in vacumm in all the inertial frames [1]. It means that the velocity of light is independent of movement of its light source. To meet the postulation, time dilation and length contraction were derived to occur in the moving frame. It needs to be noted that there is no explanation to verify the postulation, time dilation and length contraction in the paper. Since it is totally different from the conventional Newtonian mechanics, there was much debate on its validity after its publication [6].

Then, the observed light from the binary stars was used to support the special theory of relativity [6]. Binary stars are two stars rotating around each other and therefore, they are periodically moving toward and moving away from Earth. If velocity of light depends upon velocity of light source, there should be some differences in the light coming from binary stars compared with that from other stars. However, no significant difference was found in the light from binary stars. There was an argument that during travel from binary stars to Earth, light could be affected by interaction with the matter so that the difference caused by movement of binary stars could be obviated. However, that argument could not be substantiated. In 1977, X rays from binary stars were analyzed to find any effect of movement of binary stars[7]. There was not found any significant difference. Therefore, it has been recognized that the special theory of relativity is valid.

3.2 Analysis of Measured Data on Behavior of Light

Based upon advancement of electromagnetism by the scientists in the 19th century, extensive use of electricity has started with use of the electric light bulb practically invented by Thomas Edison without much knowledge on the mechanism of light generation at an atomic scale. At that time, the mechanism of light generation in an atom was not fully understood. The configuration of an atom with a nucleus with electrons in orbit was proposed much later in the 20th century. Since 1905, understanding of the light generation mechanism and interaction with the matter has been significantly advanced as explained in Section 2[8]. Based upon those advancements, dependence of light velocity upon movement of its light source will be evaluated.

The Michelson-Morley experiment shown in Figure 2 can be re-analyzed as follows. After arrival of the light at the splitter, some of the light changes its travel direction to Mirror-2, and some of the light penetrates the splitter to move to Mirror-1. Then, light is reflected after collision with both Mirror-1 and Mirror-2. In an atomic scale, light can collide elastically with the electrons in both splitter and mirrors.

If Newtonian mechanics of relative motion that velocity of light depends upon the velocity of its light source is applied to collision of the light with electrons in both splitter and mirrors, the results of the Michelson-Morley experiment shown in Figure 2 can be simply and clearly explained without employing the concept of time dilation and length contraction as follows.

When light moves depending upon movement of Earth or light source according to Newtonian mechanics,

Travel time of light in the horizontal direction(t_1) = $\frac{2L^h}{c}$

Travel time of light in the perpendicular direction(t_2) = $\frac{2L^p}{c}$

Then, as t_1 is equal to t_2, L^h is equal to L^p , consistent with the equal physical lengths of both.

If the apparatus, the same as that in the Michelson-Morley experiment with a light bulb attached as a light source is assumed to be installed inside a train, the experimental results will be always the same regardless of the velocity of the train, like the results of the original Michelson-Morley experiment.

In addition, the original analysis of Michelson and Morley experiment explained in section 3.1 has a self-contradiction. It was assumed that light moves at constant velocity independent of the movement of Earth including light source, splitter and mirror. It means also that light moves in a straight direction independent of the movement of Earth. If it is assumed that light moves independent of movement of Earth, then light from the splitter can not hit Mirror-2 in the perpendicular direction since Mirror-2 has moved away in the horizontal direction during the time for light to move from the splitter to Mirror-2. The fact that light actually arrived at Mirror-2 in the perpendicular direction shows that movement of light actually depends upon movement of the splitter and therefore, light behaves as the same as a normal object behaves in Newtonian mechanics on relative motion.

There is very reliable evidence to support the dependence of light velocity on movement of its light source. Radar is now widely used to measure the speed and the distance of the moving object using radio wave among light. As shown in Figure 1, a radio wave has a much longer wavelength and therefore it has a much lower probability to interact with gases in the air through frequency resonance. By using radar, the effect of movement of the light source on the velocity of light can be estimated more reliably. Figure 3 shows a working mechanism for radar and the moving target.

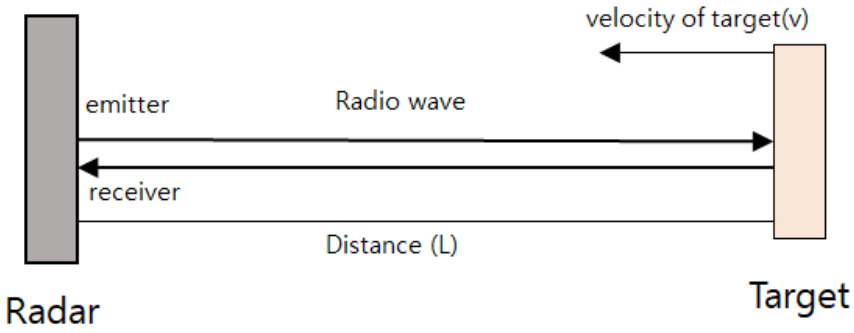

Figure 3. Radar to measure the speed and the distance of target

When the target is approaching toward the emitter in radar with velocity(v). the target receives the radio wave and reflects the radio wave back to the receiver in radar. Travel time(t_1) of the radio wave from emitter to the target is reduced by movement of the target. When the radio wave is reflected from the target, the target then becomes the secondary emitter of a radio wave, and receiver in radar becomes the secondary target. Then, the travel time(t_2) of the radio wave from the target to the receiver in radar is reduced again by movement of the target during the return of the radio wave. The equations to calculate the travel time of the radio wave are as follows.

$$t_1 = L_0/(c + v)$$
$$t_2 = (L_0 - vt_1)/(c + v)$$

where,

c = the speed of the radio wave

L_0 = initial distance between radar and target

Therefore, by measuring the time elapsed during travel of the radio wave between radar and target, dependence of the light velocity on the movement of its light source can be verified.

If the special theory of relativity that the velocity of light is constant, independent of inertial frame or movement of its light source is applied to this case of Radar and the target, the paradox occurs. Let's assume that radio waves are emitted toward each other between radar and the target at the same time. The travel time(t_1)of the radio wave from radar to the moving target is still $t_1 = L_0/(c + v)$. However, Travel time(t'_1) of the radiowave from the moving target to radar is $t'_1 = L_0/c$, since the velocity of the radio wave or the light is assumed constant regardless of velocity or movement of its source in the special theory of relativity. There occurs difference in two cases, which can not be accepted with common sense and would becomes a “radar paradox”.

In addition, there are double Doppler effects on the radio wave of radar, one from the emitter to the target and the other from the target to the receiver. By measuring the frequency change in the receiver, the velocity of the target is calculated as follows.

$$\triangle f = (2vf)/c + (v/c)^2/f \cong (2vf)/c ,$$

where,

f = frequency of the radio wave

$\triangle f$ = change of frequency of the radio wave measured at the receiver of radar

v = the velocity of the target

c = the speed of the radio wave

Radar is currently widely used to measure the velocity of the target by using the above equations. Both the double Doppler effect and the travel time reduction from the target to receiver in radar show that when the target, as a secondary source of a radio wave is moving toward the stationary receiver, the relative velocity of the secondary radio wave changes by movement of the secondary source of radio wave, that is the target. This shows that velocity of light or radio wave depends upon the movement of its light source. If measurement data of travel time of radio wave in communication between Earth station and moving satellite or spacecraft are available, those could be useful for verification.

Therefore, the results of the Michelson-Morley experiment and radar to measure the velocity of a moving object using radio wave show clearly that velocity of light depend upon velocity of the light source, obeying Newtonian mechanics, the same as other objects.

4. Discussion

There have been many experimental results used to support the special theory of relativity. They are to be re-analyzed. First is the light from binary stars as explained in Section 3.1. There are many kinds

of light depending energy, wavelength or frequency, as shown in Figure 1. Characteristic of vibration of electric charge determines the energy or wavelength of light generated. Vibration of electrons in atoms or molecules generates light mostly in visible range. Vibration of electrons in metal conductor generates radio waves. Vibration in the nucleus of an atom generates gamma rays. Light generated by these vibrations has a higher probability to interact with the matter where it was generated through resonance of frequency.

Therefore, it is quite probable that light from distant binary stars, several million light-years away from Earth may interact with the matter during a long travel. The matter could be atoms, gases and others. Lights generated from atoms in binary stars such as infrared, visible light, X ray to gamma rays tends to interact with atoms during travel. Therefore, these interaction of light with the matter during travel from binary stars and Earth could affect the lights arriving on Earth.

The temperature of sun varies a lot from the center to the surface. Most of the sun light arriving on Earth comes from light generated at the photosphere in the outer region of the sun. Light generated at inner regions can interact with the matter in the sun and therefore it could not arrive at Earth. Therefore, the light arriving on Earth from far distant stars such as visible light, X rays and gamma rays which were generated by atoms may not be much reliable to evaluate the effect of movement of a light source.

On the other hand, a radio wave is generated by vibration of electrons in a metal conductor. The wavelength of a radio wave is approximately in the range of 0.1 to 1,000 meters. Therefore, a radio wave has a very low probability of interaction with the matter of gases or atoms during travel.

As verification of time dilation, it was reported that the measured time in a satellite moving in space is different from that on Earth. Atomic clocks mostly use cesium to measure time. In a cesium atomic clock, one second is defined as the duration for certain frequencies of light emitted from the cesium atom to be detected. Since a typical energy or wavelength of light emitted from a cesium atom is known, the duration or time is measured for the fixed number of waves corresponding to one second on both Earth and satellite. Differences in time or duration for Earth and satellite were found. However, if there were difference in the frequency of light emitted from cesium atom in Earth and satellite, there may be other causes such as differences in electromagnetic field and gravity in space. There are actually efforts to minimize the noise or perturbation in the electromagnetic fields by using a single atom to measure the time more accurately. Therefore, the differences in time duration in Earth and

satellite is not a sufficient evidence to verify time dilation in the special theory of relativity. Length contraction is nearly impossible to measure since it is too small.

If the special theory of relativity is not valid. there are some subjects which need to be updated[9]. One is the estimation of energy of particle moving near light speed(c) in an accelerator. Interpretation of the special theory of relativity results in that mass(m) of a particle moving with velocity(v) increases as follows.

$$m = m_0 (1 – v^2/c^2)^{-1/2}$$

where, m_0 is the mass of a particle at rest.

Therefore, the kinetic energy of a particle moving near light speed is estimated to be very high when the above equation is applied. If the special theory of relativity is not valid, above equation can not used in estimating the kinetic energy of the moving particle. In the accelerator, a particle with an electric charge is accelerated by an electric field. There may be some interaction between the charged particle and electromagnetic fields in an accelerator. Since the particle with charge is not neutral, the equation of kinetic energy for a neutral particle, $E=1/2\cdot mv^2$ could not simply be used to calculate the kinetic energy of the particle in the accelerator. Therefore, if the special theory of relativity is not valid, re-estimation of kinetic energy of the charged particle accelerated up to near the speed of light in an accelerator would be necessary.

The general theory of relativity considers the space and the time together and is based upon interpretation of the special theory of relativity. If the special theory of relativity is not valid, the general theory of relativity using the frame of spacetime may not be necessary. Then, the universe could be analyzed by using the conventional frame of three-dimensional space and time. Considering the interaction of light from stars with the matter during a long journey to Earth, it would be worthwhile to explore more on the effects of those interactions on the measured red shift in light from stars, which may indicate the way to go beyond Big Bang theory of the universe [9].

5. Conclusion

The special theory of relativity proposed by Albert Einstein in 1905 postulates that velocity of light is independent of movement of its light source. As it is totally different from the conventional Newtonian

mechanics, it has been very difficult to understand intuitively with common sense. Based upon advancements in understanding light up to now since 1905, the dependence of light velocity upon movement of its light source was investigated.

Characteristics of light such as generation, traveling and interaction with the matter were analyzed. As light can be generated by vibration of a single electron in an exciton, light can be regarded as a discrete one, a particle or a photon. As light also shows the characteristics of transverse wave with oscillating electric and magnetic fields, light can be considered as a particle with electromagnetic wave characteristics inside, or a wave particle.

Through analysis of results of the Michelson-Morley experiment and the working mechanism of radar, it was found or verified that the velocity of light depends upon the velocity of the light source. Therefore, Newtonian mechanics on relative motion can be applied to light as same as to all the other objects.

The evidences which have been used to support the special theory of relativity, such as lights from binary stars and time dilation measured in satellites using atomic clocks were discussed to show that those can not be solid or sufficient verification. The subjects which need to be updated when the special theory of relativity is not valid, such as the estimation of the kinetic energy of the accelerated particles and the general theory of relativity were discussed.

As the conventional Newtonian mechanics is applied to light, physics and the universe could be more easily conceivable and accessible by using the frame of three-dimensional space and time, which may pave the way to overcome the difficult concepts such as singularity, dark energy and dark mass.

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Declaration

Ethical approval - Not Applicable

Consent to participate - Not Applicable

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