Particle Model Of Light

Hakan Eğne
Independent Researcher & Physicist

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Abstract

Two centuries after Thomas Young, with the development of technology, an experimental system that sends photons to the screen one by one was developed and the Young experiment was repeated. Surprisingly, in the double slit experiment, the same interference patterns occurred when individual photons were sent to the slits. This article will show you that it is possible to explain bright-dark fringes with the particle model of light also.

CHAPTER I

INTRODUCTION

At Figure 1.1 below, you see Interference of single photons on double slits experiment. As shown in photos, a photon leaves a trace at only one point on the screen. But as time passes, the traces left by tens of thousands of photons on the screen create interference patterns. If you look at patterns carefully, you will see traces of all photons have the same brightness on screen, even in dark regions. At Figure 1.1 a , 1st trace is in the dark region, and 2nd is in the bright region.

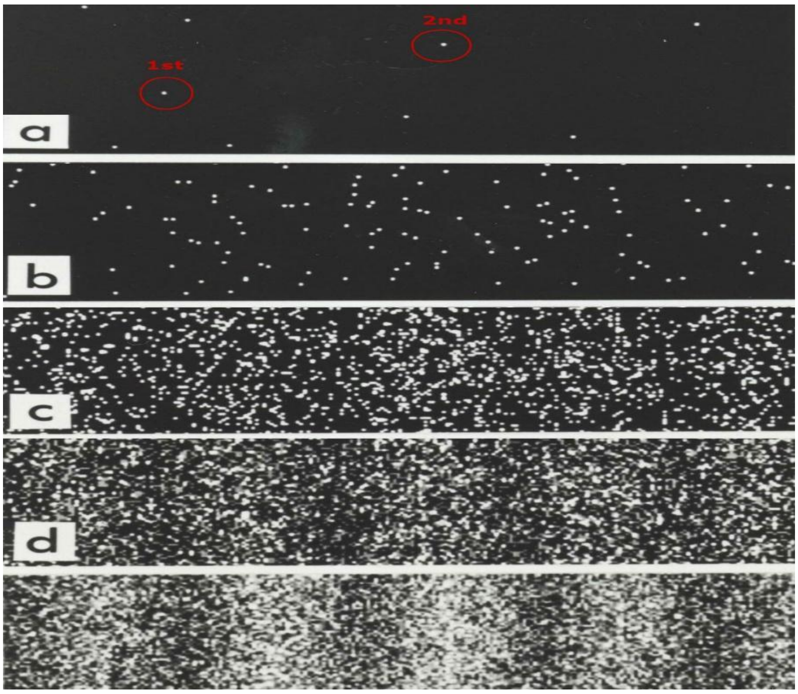

Figure 1.1 - Interference pattern of single photons

In quantum physics, this phenomenon is explained by wave function. But, A wave function in quantum physics is a mathematical description of the quantum state of an isolated quantum system. (Thorsten Gressling, 2020). The wave function ψ associated with a moving particle is not an observable quantity and does not have any direct physical meaning. It is a complex quantity. (Oreilly, 2021) It is a useful tool when calculating physical things, but it is not physical in itself.

In this article, I will show you that it is possible to explain bright-dark fringes with the particle model of light also. There is another way to explain bright-dark fringes without wave function. For this first, we will take a look at the Stern-Gerlach experiment.

A. Stern-Gerlach Experiment

With the experiment carried out by Otto Stern and Walther Gerlach in 1922, we have learned more information about the magnetic moments of electrons. In the Stern–Gerlach experiment, silver atoms travel through an inhomogeneous magnetic field and are deflected up or down depending on their spin (Gerlach, W.; Stern, O. , 1922).

I will develop a new experimental system based on the Stern-Gerlach experiment. Front (a) and side(b) views of the Stern-Gerlach Experiment Setup can be seen in Figure 1.2. In the experimental system that I will create, I will use its side view. For simplicity, I will call it the "**SG setup**" instead of the Stern-Gerlach experiment setup.

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a b

Figure 1.2 - Front (a) and side (b) views of the "Stern-Gerlach experiment setup"

Also, I will name the deflection angles of the particles as + α and -α in the SG setup.

Suppose we put two SG setups side by side (see Figure 1.3). Particles deviating from the 1st SG setup with an angle of ± **α** will have a deflection angle of ± **2α** after leaving the 2nd SG setup. For each SG setup added, an **α** angle is added.

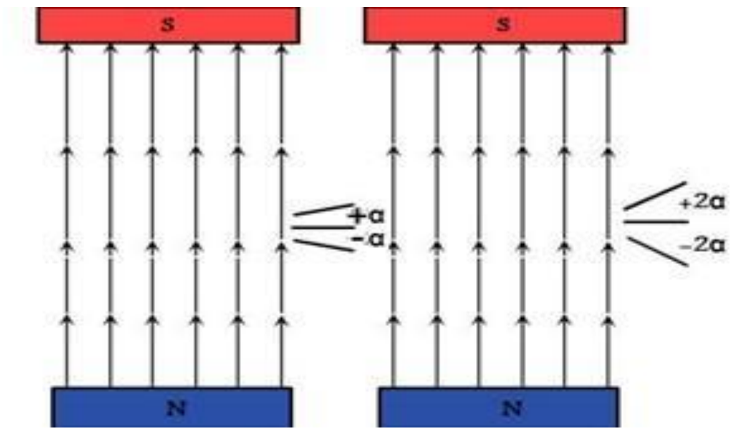

Figure 1.3 - Two SG setups

Lets reverse the 2nd SG setup (see Figure 1.4); Suppose, after the 1st SG setup, the particle is deflected upward with an angle of **+α.** The particle will be deviated downward with an angle **-α** after the 2nd SG setup. Hence **+α** and **-α** cancel each other out. In other words, when the particle leaves the two SG setups , it moves parallel to the x axis.

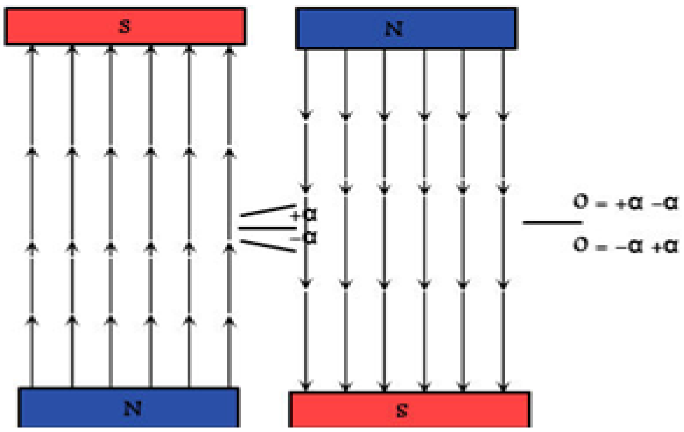

Figure 1.4 - Two opposite SG setups

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Briefly, If two SG setups have the same magnetic field direction, the angle will be ± **2α,** if they have opposite direction, the angle will be 0.

If we do not know if the magnetic field is in the same or opposite direction in SG setups, we calculate all the possibilities. As a result, 3 paths occur; **+2α**, **0**, and **-2α**. (see Figure 1.5)

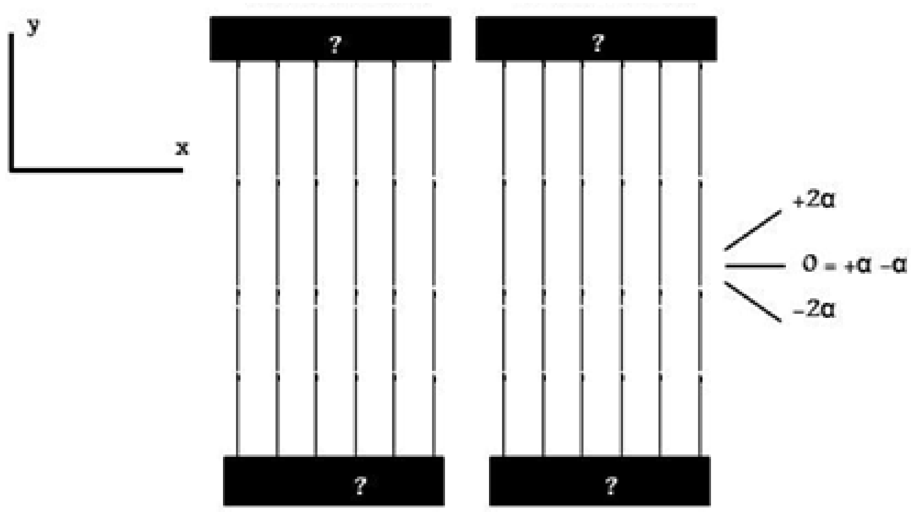

Figure 1.5 - All paths that particle can go

The system consisting of more than one "SG setup" will be called "**SG system**" in the rest of the article.

Let's add a 3rd SG setup to the **SG system** (see Figure 1.6) and calculate the paths that particles can go. When all SG setups are in the same direction, the deflection angle of particles will be **+3α** or **-3α**. If one or two of the SG setups are in opposite directions, the deflection angle will be ± **α**.

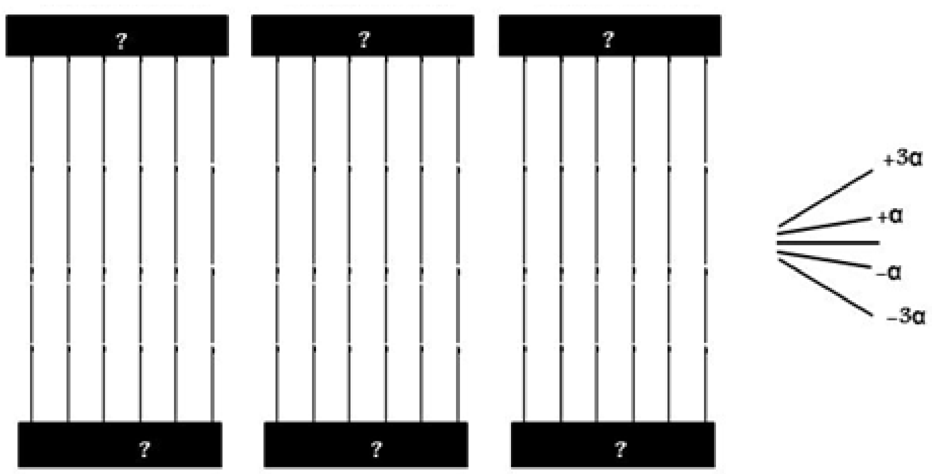

Figure 1.6 - Triple SG system

When we calculate all the probabilities, 4 different paths occur. ± **3α** and ± **α**.

Based on all this information, let's develop a larger experiment consisting of N sets of SG setups (see Figure 1.7). The number of paths that particles are likely to follow through this system will be equal to N + 1. Deviation angles will be 0, ± α, ± 2α, ± 3α… ± Nα.

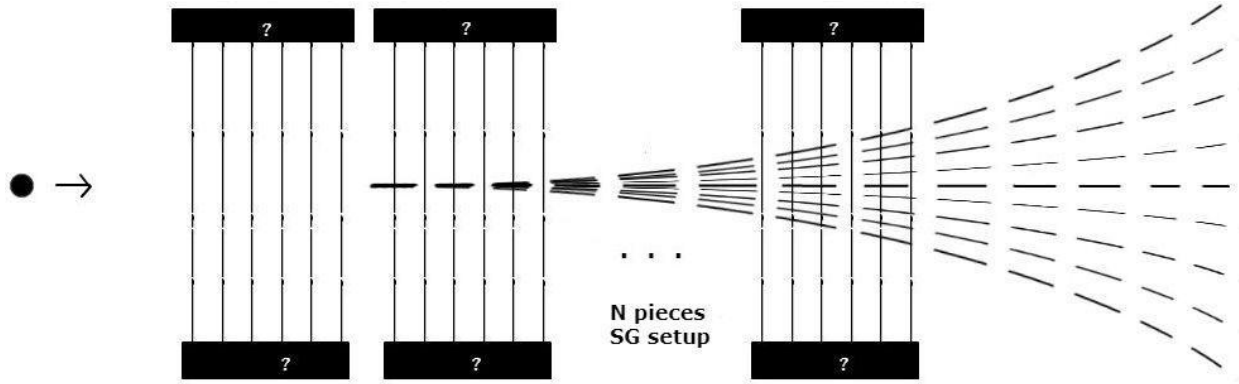

Figure 1.7 - N pieces of SG setup

Each SG setup will create path pairs. All SG setups will create a path tree as seen in Figure 1.8

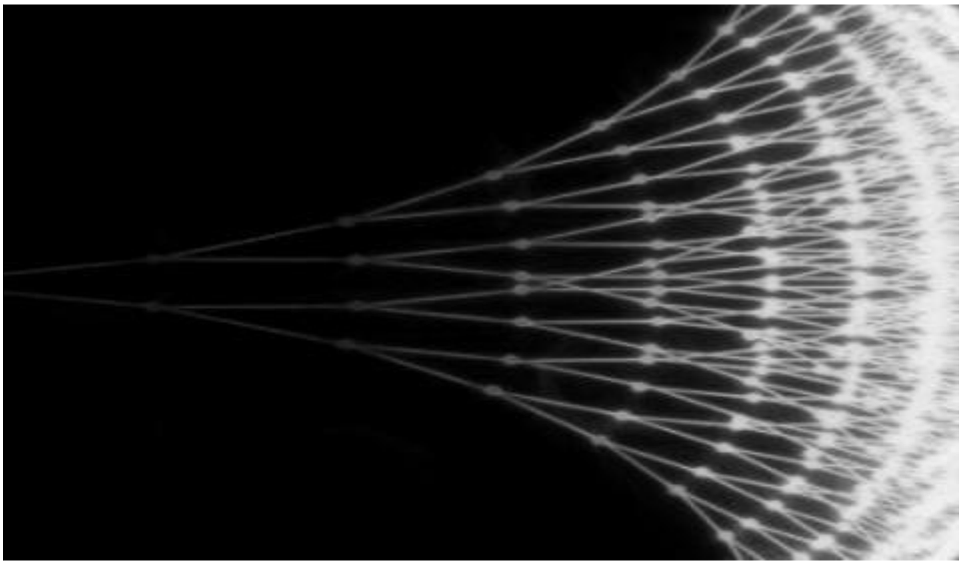

Figure 1.8 – Path tree created by SG setups

Which path and how often do particles pass? In order to make calculations, I simulated the SG system on the computer and did an experiment with 10 million particles. Different SG systems were created for each particle and random N pieces SG setup were created in each SG system (100<= N <= 109).

For example, 101 SG setups for the 1st particle were placed side by side and the magnetic field direction of each SG setup was randomly generated up or down. For the 2nd particle, 108 SG setups were placed side by side and again the magnetic field direction of each SG setup was randomly generated up or down. This process was repeated 10 million times. A graph like in Figure 1.9 appeared.

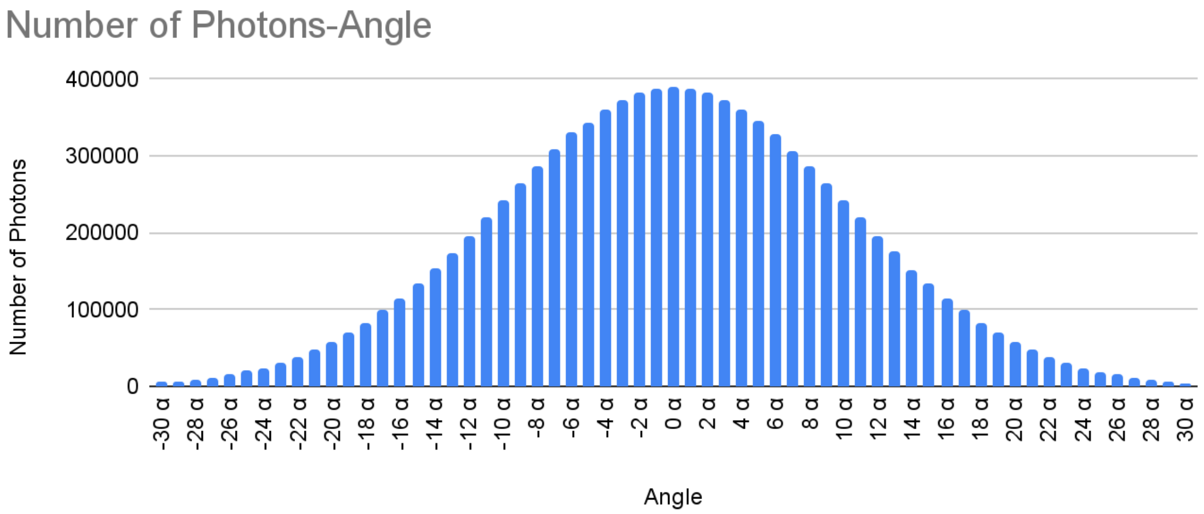

Figure 1.9 - Gaussian distribution of particles

As can be seen in Figure 1.9, the density distribution of the **particle paths (α)** in the simulation of the SG system is similar to the density distribution of photons in double slit experiment. As seen in the graph when deviation angle increases, the number of particles decreases. Figure 1.10 shows distribution of particles.

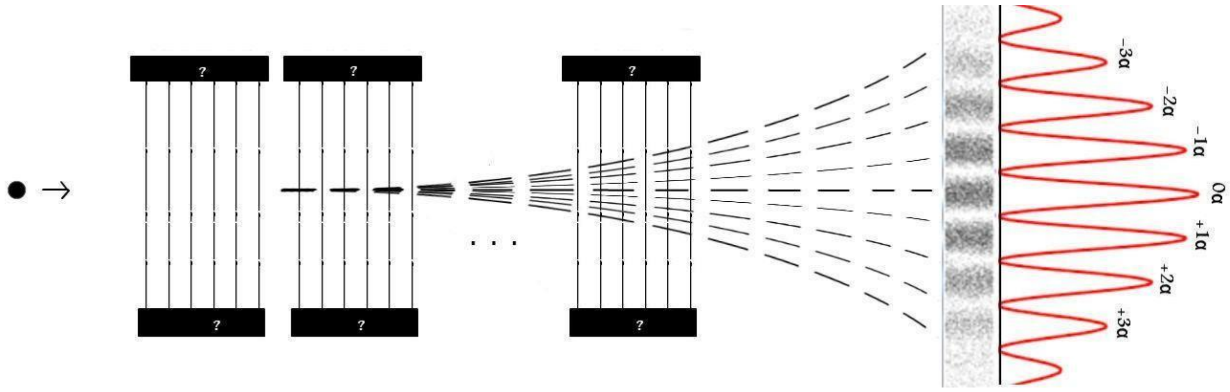

Figure 1.10 – The paths of the particles and the density distribution of the particles passing through these paths.

In the next chapter, we will discuss the effects of slit surfaces on photons at double/single experiments. You will see similarity between double/single slit experiments and the SG system above.

CHAPTER II

ELECTRIC FIELD OF SLIT SURFACES AT DOUBLE SLIT AND SINGLE SLIT EXPERIMENTS

In the double/single slit experiment, the effect of the slit surfaces on photons is neglected and only the properties of the light are taken into account. But when we examine the surface of the slits, we see opposing electric and magnetic fields that differ in atomic size.

In imaging techniques such as AFM (Atomic Force Microscope), STM (Scanning Tunnelling Microscope), MFM (Magnetic Force Microscope), these atomic-sized electrostatic and magnetostatic forces on the surface are used. These imaging techniques have shown us that when we consider surfaces on a nanoscale, we cannot think of them as one-piece neutral as in classical physics.
(see Figure 2.1).

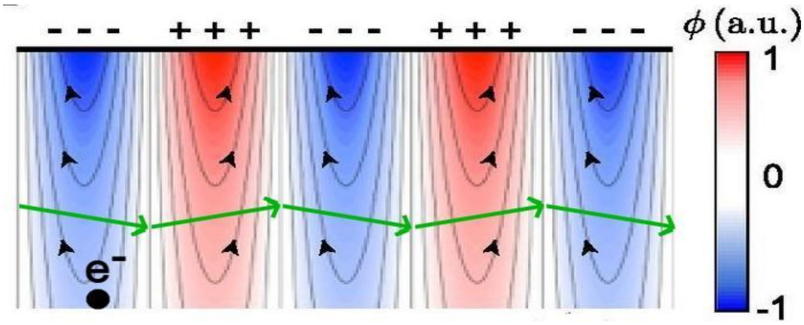

Figure 2.1 – Electric field of surface charges

As in the SG system above, the forces acting along the path change direction of particles. These forces act on the particle randomly upward or downward along the path, and deviations occur in the path of the particle. The cumulative sum of these paths causes the particles to concentrate in certain areas, resulting in bright-dark patterns.

A situation similar to the SG system above occurs between the slit surfaces and the photons. Each photon passing through a path close to the surface is under the effect of different electrostatic and magnetostatic forces. Either both or only one of these forces act on the photons, causing the paths of the photons to change.

But, since all electrostatic forces of positive and negative charges on the surface act simultaneously on **macro objects**, the resultant of the total forces becomes 0 and the macro objects pass through the slits without being affected. But only one of these forces acts on **nano particles** like atoms, electrons, photons at a particular time and location. Not all of them act at the same time.

A. Static Electric & Slit Surfaces

As known, when a charged object is brought close to an uncharged surface, the surface becomes polarised. An electric field occurs between the charged body and the surface. As the charged object approaches the surface, the electric field strength between them increases. We know this from Coulomb's law. In an insulator, electrons redistribute themselves within the atoms or molecules closest to the outer surface of the object. (see Figure 2.2).

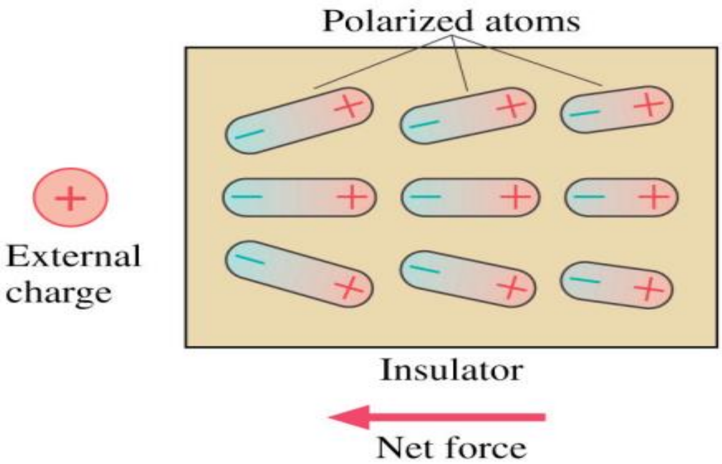

Figure 2.2 – Polarisation between charged body and the surface.

When two neutral surfaces approach each other, charged particles dispersed on the surface interact with charged particles on the opposite surface. Charged particles on the surface create micro-electric fields between surfaces. As the surfaces get closer, the intensity of these electric fields increases (see Figure 2.3).

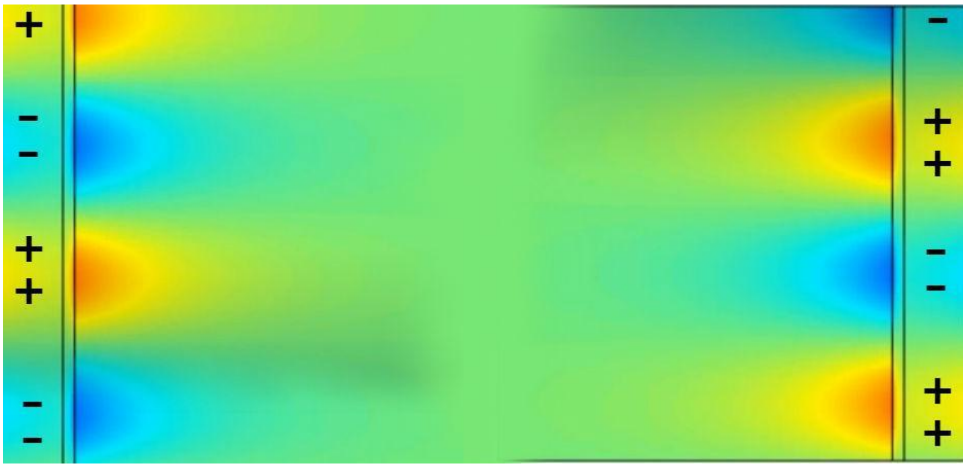

Figure 2.3 – Polarisation between surfaces

B. Electric Dipole Particle Photon

As you know from pair production, gamma ray photons can transform into electrons and positrons. And at pair annihilation phenomena, electrons and positrons can merge into gamma ray photons. Based on these events, **we will consider the photon as an electric dipole particle** consisting of a particle and antiparticle.

In Figure 2.3 above we have mentioned that electric field of surfaces. Let's investigate the motion of dipole photons in the electric field of the surface. As seen, dipole photons pass through many inhomogeneous unit electric fields of the surface during motion, as the SG system we explained above. So, we will see a bright-dark interference pattern with dipole photons as in the SG system experiment above. (see Figure 2.4).

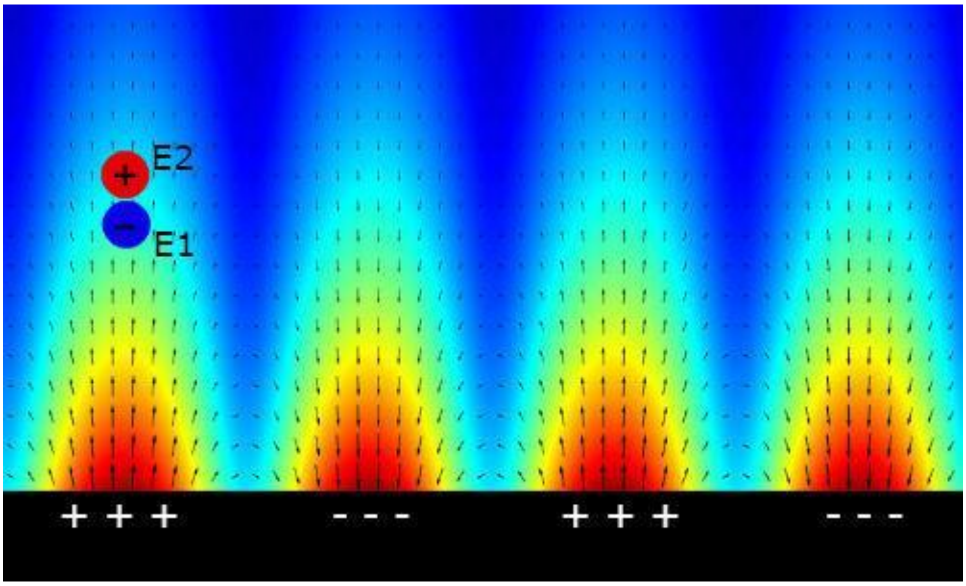

Figure 2.4 – Photon Motion in Inhomogeneous Surface Electric Fields

If we call the force applied to the negatively charged particle $\mathbf{F_1}$ and the force applied to the positively charged particle $\mathbf{F_2}$;

$\mathbf{F_1 = - q.E_1}$ (force on negative charged particle of photon, **E** electric field **q** charge)

$\mathbf{F_2 = + q.E_2}$ (force on positive charged particle of photon)

$\mathbf{F_{net} = F_1+F_2 = (-q.E_1) + (q.E_2) = q(E_2 - E_1)}$

$\mathbf{F_{net} = q.\Delta E}$

Let's divide these electric fields into equal parts of width L and examine them closely as seen in Figure 2.5. The dipole particle deviates**,** after travelling **L** distance in the electric field. Dipole travels in the electric field with velocity v for the time t. During the time in the field, it is accelerated downward along the **y-axis** with acceleration **a**. We can calculate the value of **Δy** with the formula below.

$$\Delta y = \frac{1}{2}at^2 = \frac{1}{2}\frac{F}{m}\left[\frac{L}{v}\right]^2 = \frac{1}{2}\frac{q\Delta E}{m}\left[\frac{L}{v}\right]^2$$

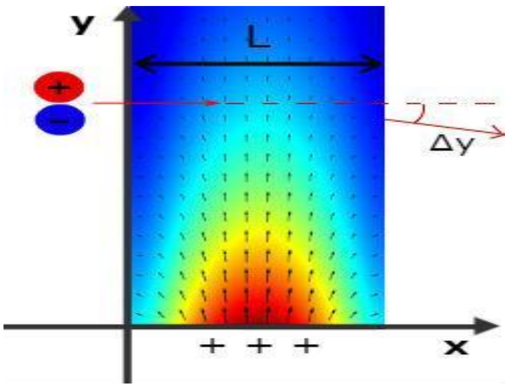

Figure 2.5 – Unit electric field

In the equation $\mathbf{F_{net} = q.\Delta E}$, if the charge value of **q** increases, the attraction force between positive and negative charged particles increases and the particles come closer to each other. Therefore **ΔE** value decreases. If the magnitude of charge doubles, the value of **ΔE** decreases by half. The $\mathbf{F_{net}}$ value always remains **constant** regardless of the charge magnitude of the charged particles.

$$\Delta y = \frac{1}{2}at^2 = \frac{1}{2}\frac{F}{m}\left[\frac{L}{v}\right]^2 = \frac{1}{2}\frac{q\Delta E}{m}\left[\frac{L}{v}\right]^2$$

In the above equation, " **q.ΔE** ", "**L**", "**v**" values are constant (v=c). Only "**m**" value changes. “**m**” is the virtual mass of a photon. As known, photons even though really don't have mass, can act like they do have mass. So there is some mass equivalent to a photon, calculated by formula $\mathbf{hf = "m"c^2}$

As known, in gravitational redshift, **virtual mass** is calculated and used in equations. In physics, gravitational redshift is the phenomenon that electromagnetic waves or photons travelling out of a gravitational well lose energy. This loss of energy corresponds to a decrease in the wave frequency and increase in the wavelength, known as a redshift. (Wikipedia, 2019)

$$E_{final} = E_{initial} - E_{lost\ to\ overcome\ gravity}\ (Potential\ energy)$$

$$hf_{final} = hf_{initial} - G\frac{"m"M}{R}$$

$$"m" = \frac{hf}{c^2}$$

$$hf_{final} = hf_{initial} - \left(\frac{hf}{c^2}\right)\frac{GM}{R}$$

Above equations are used to calculate the gravitational redshift of a photon. Any light that tries to get away from a large object will lose energy. In equations, “m” is the virtual mass of a photon, M is the mass of a large object such as a neutron star, star or black hole.

When the frequency of the photon increases, so does its energy. As energy increases, its virtual mass “**m**” increases. When the frequency and hence energy of the photon doubles, its virtual mass “**m**” doubles.

$$\Delta y = \frac{1}{2}at^2 = \frac{1}{2}\frac{F}{m}\left[\frac{L}{v}\right]^2 = \frac{1}{2}\frac{q\Delta E}{m}\left[\frac{L}{v}\right]^2$$

Notice also in the above equation, when the virtual mass “**m**” doubles, the deviation **Δy** decreases by half. If the value of **Δy** is reduced by half, it means that the length of interference fringes are reduced by half. The width of the interference fringes is neither related to frequency nor to wave properties. The change in the length of interference fringes depends on the virtual mass “**m**”. If “**m**” increases, the length of interference fringes decreases.

C. Difference Between Double Slit & Single Slit

In a single slit, since the electric field is homogeneous in the middle region of two surfaces, $\mathbf{F_{net} = 0}$. So there is no deviation here and the photons move to the screen without deviation (see Figure 2.6). Therefore, in the single slit experiment, the luminous fringe in the middle becomes brighter than the others. Only photons near surfaces will be deflected.

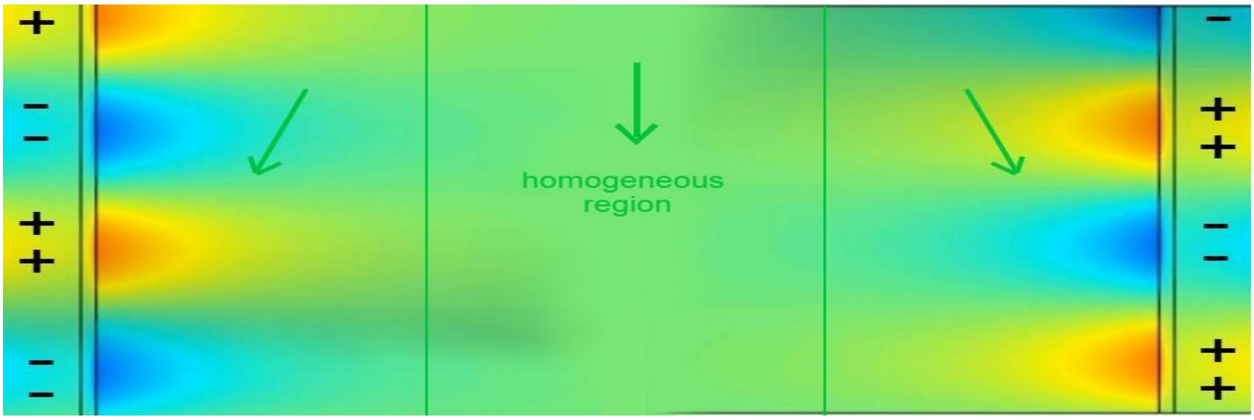

Figure 2.6 – Single slit electric field

Before talking about double slits, it should be noted that Thomas Young did this experiment with a single card, not with slits. The double-slit experiment is done with a thin object, not with slits as thought. For example, you can perform this experiment with a thin wire or card.

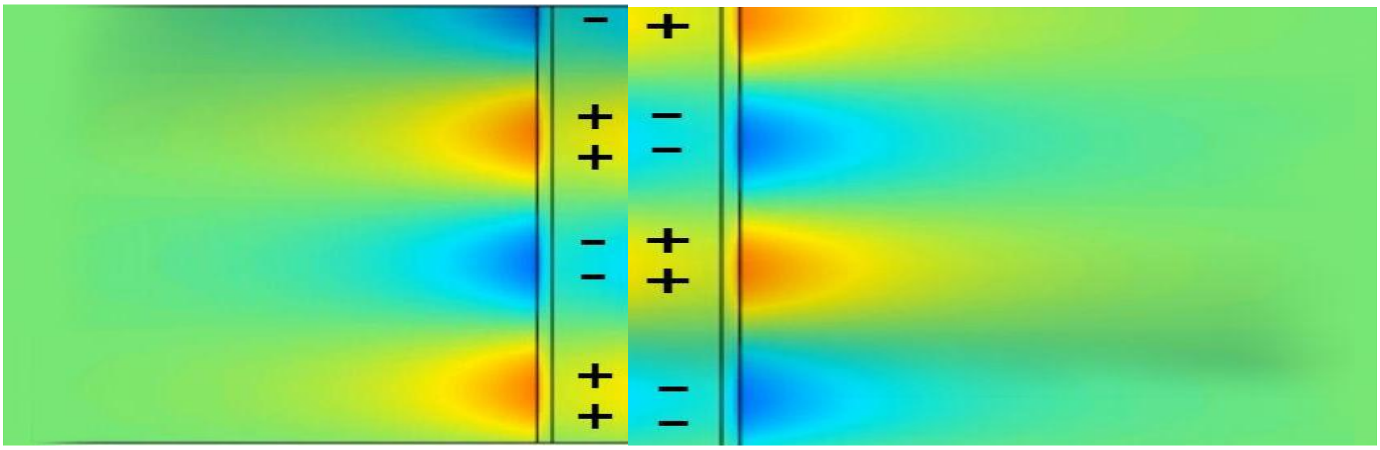

Figure 2.7 – Slit surface electric field (slim card)

The difference between double slit and single slit is; surface of the single slit looks at each other, but the surface of the double slit opposite of each other. But both of them work with the same logic; If surfaces come closer to each other, the strength of the surface electric field increases. Not important, they are face to face or opposite to each other.

As seen, at Figure 2.6 and 2.7, electric fields aligned perfectly. For interference patterns to occur, the electric fields must be perfectly aligned. However, when you put a detector to observe which slit the light passes through, this perfect arrangement is disrupted. That's why we can never observe which slit light passes through.

CHAPTER III

THOMSON SCATTERING

As known, Thomson scattering is the scattering of the photon by the electron in the presence of $\mathbf{hv \ll m_e c^2}$. In other words, it is the scattering of the photon by the electron when the energy of the photon is much smaller than the static mass energy of the electron. There is no energy transfer in this scattering (Chen, 1998). Let us examine this phenomenon by thinking the photon as an electric dipole particle;

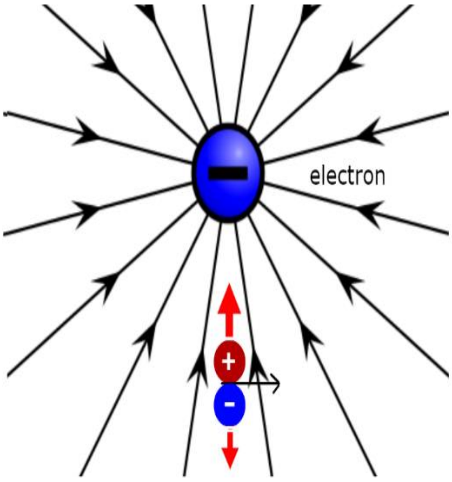

Figure 3.1 – Interaction of positive and negative charged particles of photon and electron.

As seen in Figure 3.1, the electron has an inhomogeneous electric field. As the photon passes by the electron, the positively charged particle of the photon is attracted by the electron, while the negatively charged particle is repelled by the electron. We already know this from the Coulomb law. But because the positively charged particle is closer to the electron, the pulling force is greater than the repulsive force. The magnitude of the force deflecting the photon; $\mathbf{F_{net} = F_{attractive} - F_{repulsive} > 0}$

As the photon changes direction with the F_{net} force, it gets closer to the electron. After reaching the nearest point to the electron, the photon continues to move away from the electron (see Figure 3.2).

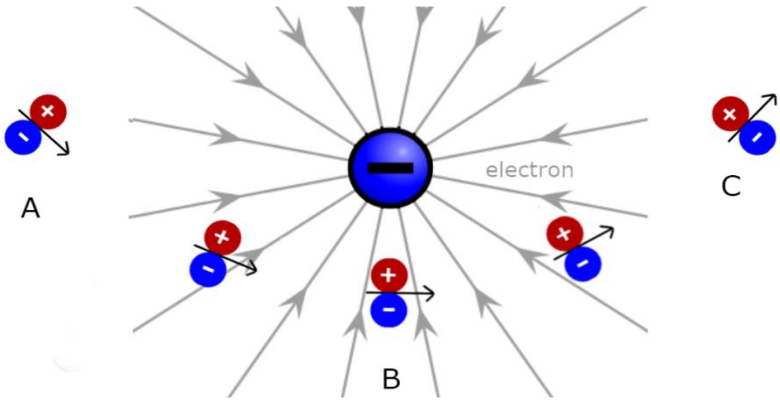

Figure 3.2 – Movement of the photon between A-B points and B-C points.

As can be seen in Figure 3.2, the photon comes to the closest position to the electron at the B point. As the photon travels from point A to point B, its energy increases with the effect of positive acceleration, while moving from point B to point C, its energy decreases with the effect of negative acceleration. When the photon leaves the electric field of the electron, its first and last energy will be the same and therefore its energy will not change. The energy gained while approaching the electron is given back as it moves away from the electron.

We can compare this to an oscillating motion that gains kinetic energy under the effect of gravity (see Figure 3.3).

The object, whose kinetic energy is zero at point K, moves from point K to point O, its kinetic energy increases and reaches the maximum kinetic energy at point O. As it moves from point O to point L, its kinetic energy decreases with the effect of negative acceleration and becomes zero at point L. So the first energy and the last energy will be equal to each other.

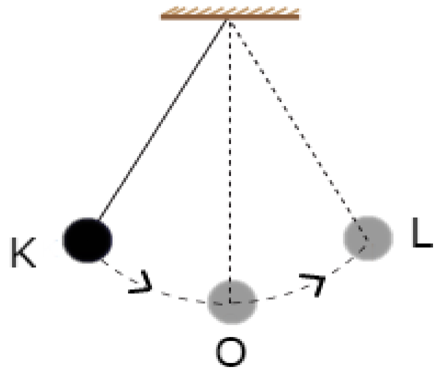

Figure 3.3 – The oscillating motion.

As we know from Coulomb's law, while the electron exerts an attraction force on the photon, the photon exerts an attraction force on the electron also. The electron, which is stretched like a spring by the **Fnet** force (see Figure 3.4), retracts and oscillates by the electrostatic attraction force of the nucleus when the photon goes away (see Figure 3.8).

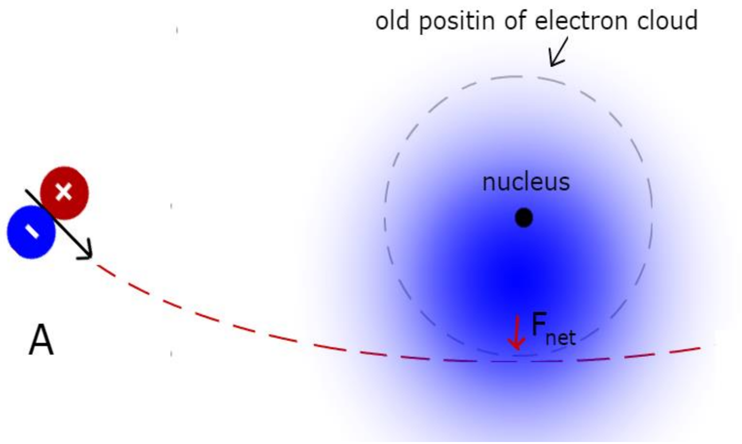

Figure 3.4 – The electron is attracted towards the photon by the Fnet force.

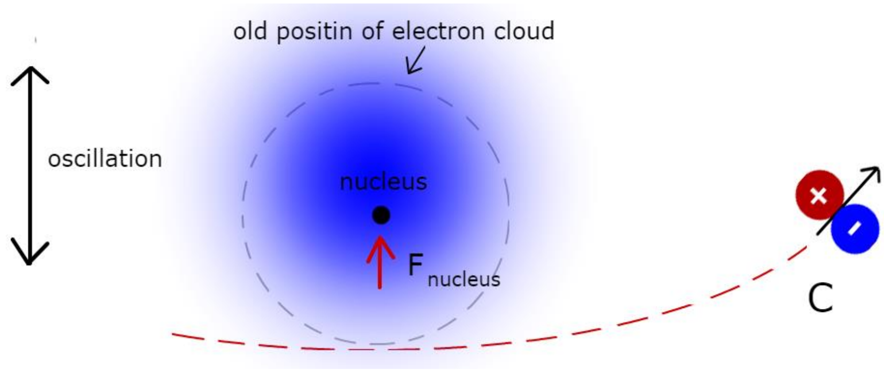

Figure 3.5 – The electron is pulled back like a spring by the attraction force of nucleus and starts oscillating

A. Compton Scattering

As known, in Compton scattering, when the high-energy x-ray photons hit the static electron, some of its energy passes to the electron and the electron gains speed. Since some of the energy of the photon passes to the electron, its energy and frequency decreases (Compton, 1923).

Since the electron is not a solid body, a collision cannot occur like in classical physics. It is therefore necessary to reconsider compton scattering. When two electrons collide, there is no such collision as in classical physics. With the electrostatic effect, the electron clouds repel each other and behave as if there is a collision.

If we consider the X-ray photon as a dipole, $\mathbf{F}_{\mathbf{net}}$ force occurs between photon and electron as in Thomson scattering. But the energy of the x-ray photons in Compton scattering is much higher than the energy of the photons in Thomson scattering. Therefore, the X-ray photon momentum is greater than the photon momentum in Thomson scattering. As the electron tries to attract the photon to itself, it is also pulled towards the photon. Because the photon has higher momentum, the electron moves farther from the atomic nucleus. Since the displacement is greater than the Thomson scattering, the electron is detached from the atom(see Figure 3.6).

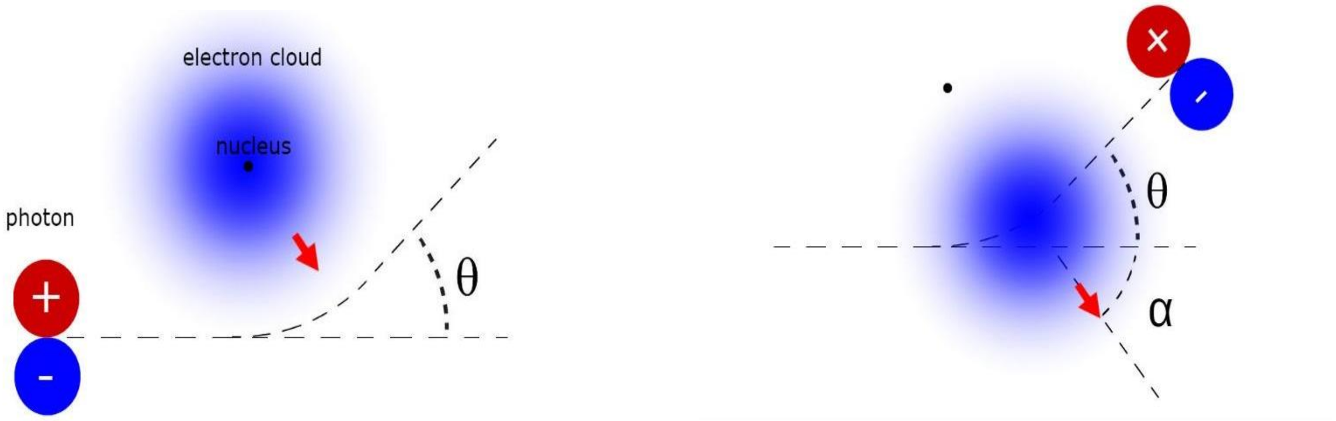

Figure 3.6 – X-Ray Photon's deflection and electron gaining kinetic energy in Compton scattering

According to the law of conservation of momentum, the total momentum of the system does not change. Before the scattering event, the electron is treated as sufficiently close to being at rest. After scattering, the possibility that the electron might be accelerated to a significant fraction of the speed of light. it results in a decrease in energy (increase in wavelength) of the photon. Part of the energy of the photon is transferred to the recoiling electron. Since the speed of the photon does not change, its frequency and energy have decreased.

B. Pair Production

As known, pair production is the event of the transformation of a high-energy gamma photon into an electron and a positron as it passes by a nucleus. Energy and momentum are conserved in this event. The rest mass energy of an electron and a positron is 0.51 MeV. Therefore, the minimum energy of the incident photon should be 1.02 MeV. Let's take the photon as a dipole particle and examine the pair production again.

As the photon passes by a positively charged nucleus, the negative charge in the photon is attracted by the nucleus, while the positive charge is repelled by the nucleus (see Figure 3.10).

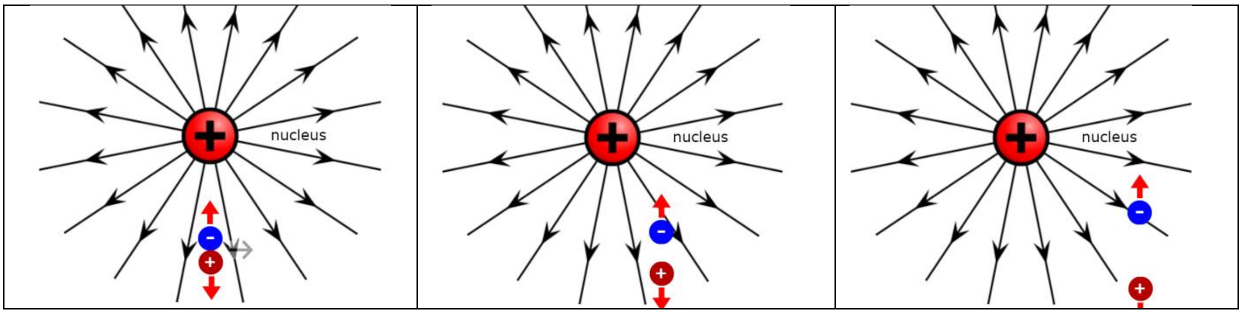

Figure 3.7 – The separation of the gamma photon passing by the nucleus into two particles

Lets call the electrostatic force between negative and positive charges of photon as $\mathbf{F}_{\mathbf{photon}}$;
There are 3 forces acting on photons. $\mathbf{F}_{\mathbf{photon}}$, $\mathbf{F}_{\mathbf{attractive\ (by\ nucleus)}}$, $\mathbf{F}_{\mathbf{repulsive\ (by\ nucleus)}}$.

$$\mathbf{F}_{\mathbf{net}} = \mathbf{F}_{\mathbf{attractive}} - \mathbf{F}_{\mathbf{repulsive}}$$

If $\mathbf{F}_{\mathbf{net}} > \mathbf{F}_{\mathbf{photon}}$, the photon splits into two parts. We call this event as pair production. Because the electric field is more dense near nucleus than electron's electric field, $\mathbf{F}_{\mathbf{net}}$ is greater than $\mathbf{F}_{\mathbf{photon}}$.

Photon does not split into two parts in Compton and Thomson scattering, because $\mathbf{F}_{\mathbf{net}} < \mathbf{F}_{\mathbf{photon}}$. It just changes its direction.

C. Polarisation

Let's think of the photon as a dipole particle and consider polarisation again. Polarisation is also closely related to Thomson scattering.

If we rotate the photon 90 degrees on the axis of travel, positive and negative charges will have the same distance to the electron (see Figure 3.5). Hence the attractive and repulsive forces are equalised. So $\mathbf{F}_{\mathbf{net}} = \mathbf{0}$.

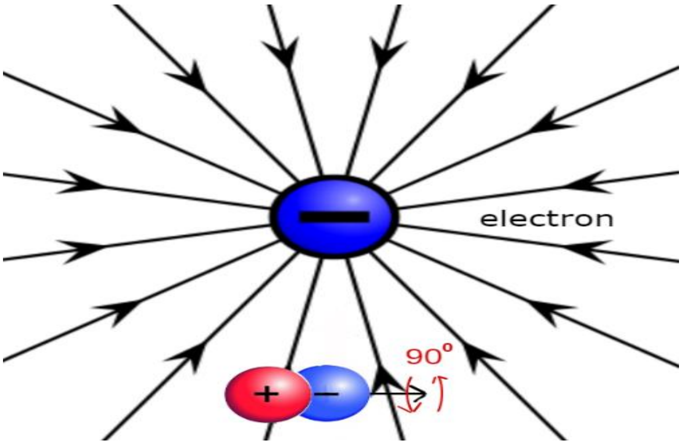

Figure 3.8 – Dipole photon rotated 90 degrees on the axis of motion.

Since $\mathbf{F}_{\mathbf{net}} = \mathbf{0}$, the photon moves without deviation. If we rotate it 90 degrees more (180 degrees in total), the negative charged particle of the photon will be closer to the electron and the repulsive force will be greater than the attractive force. This causes the photon to move away from the electron. If we rotate it 90 degrees more (270 degrees in total), the distance of the positive and negative charged particle to the electron will be equal and $\mathbf{F}_{\mathbf{net}} = 0$ (see Figure 3.9).

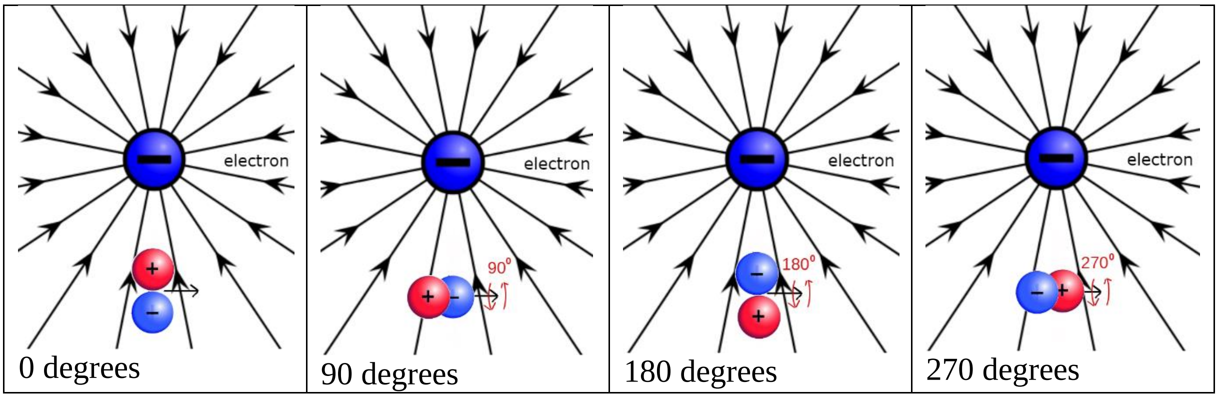

Figure 3.9- The state of the photon rotated 0, 90, 180 and 270 degrees.

As seen in Figure 3.9, when the photon is at 90 and 270 degrees, $\mathbf{F}_{\mathbf{net}} = \mathbf{0}$. At 0 and 180 degrees $\mathbf{F}_{\mathbf{net}} \neq \mathbf{0}$ and photons are deflected.

Let's assume that 4 photons at 0, 90, 180 and 270 degrees pass in the non-homogeneous vertical electric field as shown in Figure 3.7 (field is from bottom to top according to the screen). 0 and 180 degree photons will change their direction and only 90 and 270 degree photons will reach the observer without deviation. So, 50% of the photons will reach the observer (see Figure 3.10).

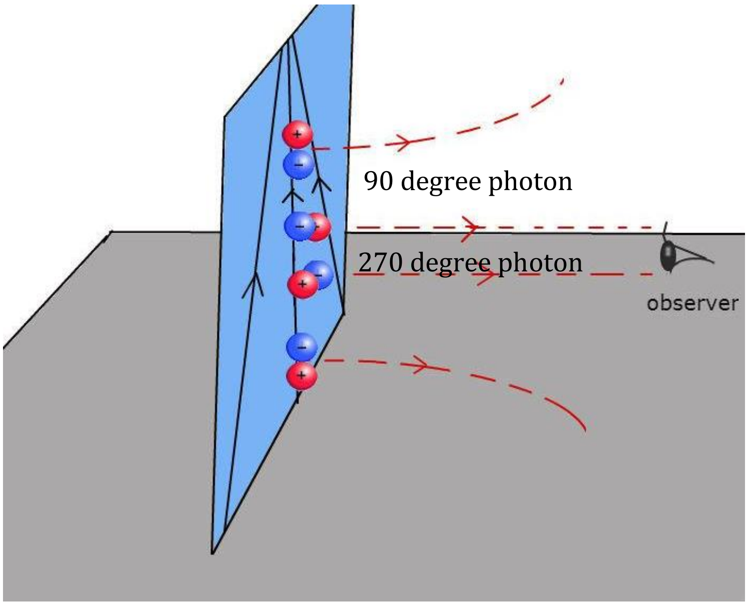

Figure 3.10 - 4 photons at 0, 90, 180 and 270 degrees while passing through the vertical field

Photons at 90 degrees and 270 degrees will pass through the vertical field without deviating. But while passing through the horizontal electric field, one deviates towards the outside of the screen and the other deviates into it and does not reach the observer (see Figure 3.11).

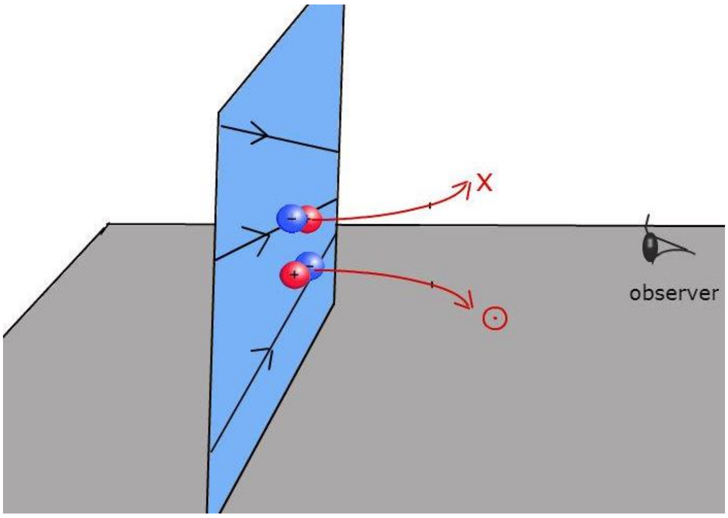

Figure 3.11 - 2 photons at 90 and 270 degrees will be deflected, when passing through the horizontal electric field.

Briefly, only 50% of the photons passing through one of the vertical or horizontal fields reach the observer. All photons passing through both horizontal and vertical electric fields are scattered and no photons reach the observer. This situation is also observed in polarisation filters. 50% of the photons passing through the horizontal or vertical filter reach the observer. If horizontal and vertical filters are used together, none of the photons reach the observer (see Figure 3.12).

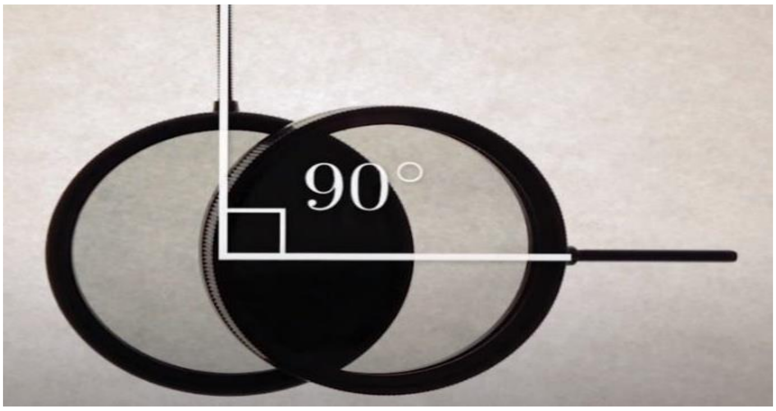

Figure 3.12 –Two filter (horizontal and vertical)

Photons seem to be affected by the electromagnetic field, according to the above explanation. However, you might say photons are not affected by the electromagnetic field. When you put a third filter at a 45 degree angle between the horizontal and vertical polarisation filters, it was seen that 25% of the photons reach the observer (see figure 3.13). It is clearly seen here that 25% of the photons coming out of the horizontal filter, became vertical polarised while they were horizontal. otherwise, It is impossible to pass through the vertical filter. In this case, there must be a force that turns photons from horizontal to vertical polarisation. As known, the universe is based on 4 fundamental forces. The force that turns the photons must be one of these four forces. It cannot be a weak and strong nuclear force because its range of action is too short. Gravity can't be because it's too weak. Only the electromagnetic force remains. As you can see, photons are affected by the electromagnetic field of electrons.

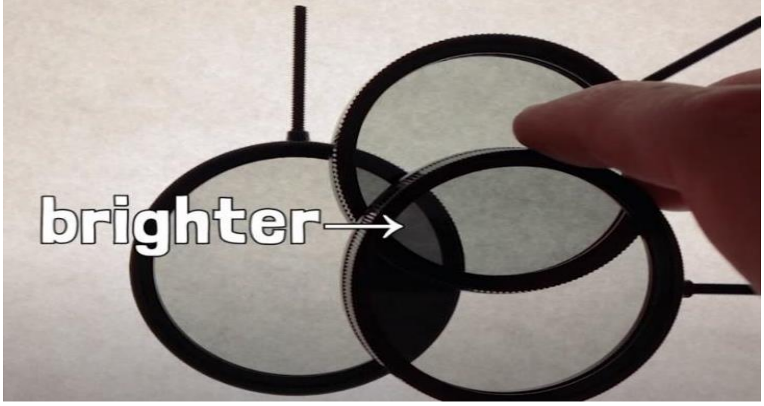

Figure 3.13 –Three filters (horizontal, vertical and between them 45 degree filter)

D. Reflection and Refraction

If we think of the reflection of light as the reflection of billiard balls by hitting the surface, another problem arises. This problem is that atomic surfaces are not flat. If we look at the flat surface with an electron microscope, we see a rough surface made up of atoms. As can be seen in Figure 3.14, photons hitting such a surface are reflected at different angles and scattered, and a symmetrical reflection does not occur. So how does symmetrical reflection occur despite this rough surface?

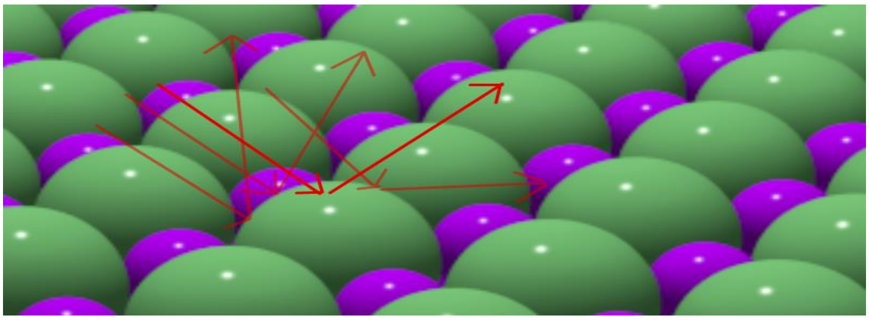

Figure 3.14 –Reflection of photons from surface in atomic size

The reflection event and the Thomson scattering event are the similar events. In a reflection event, photons are reflected by the electrons of the atoms on the surface, like Thomson scattering.
(see Figure 3.15)

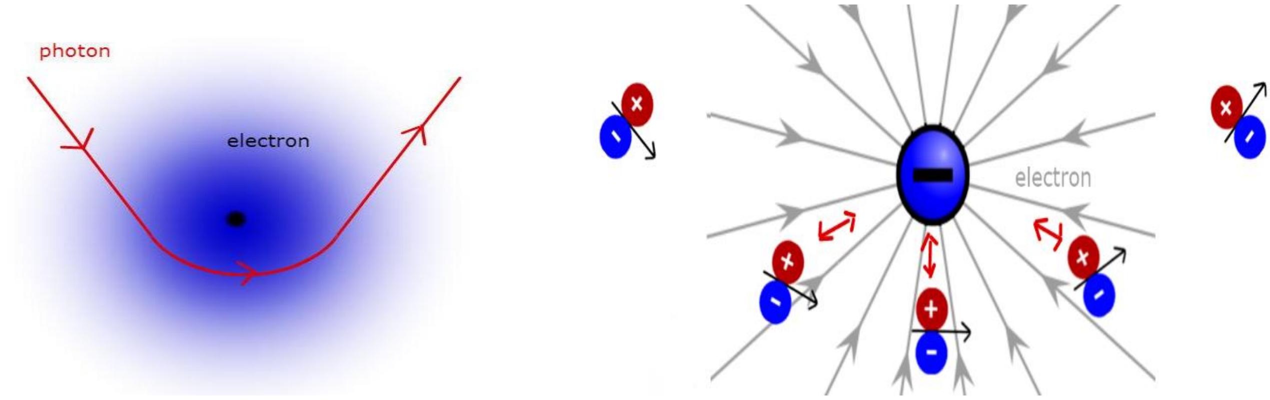

Figure 3.15 –Reflection of photons by electron’s electric field

The reflection event is not actually a flexible collision event with the surface. It is the change of direction of photons as a result of electrostatic force between photon and electron (see Figure 3.15).

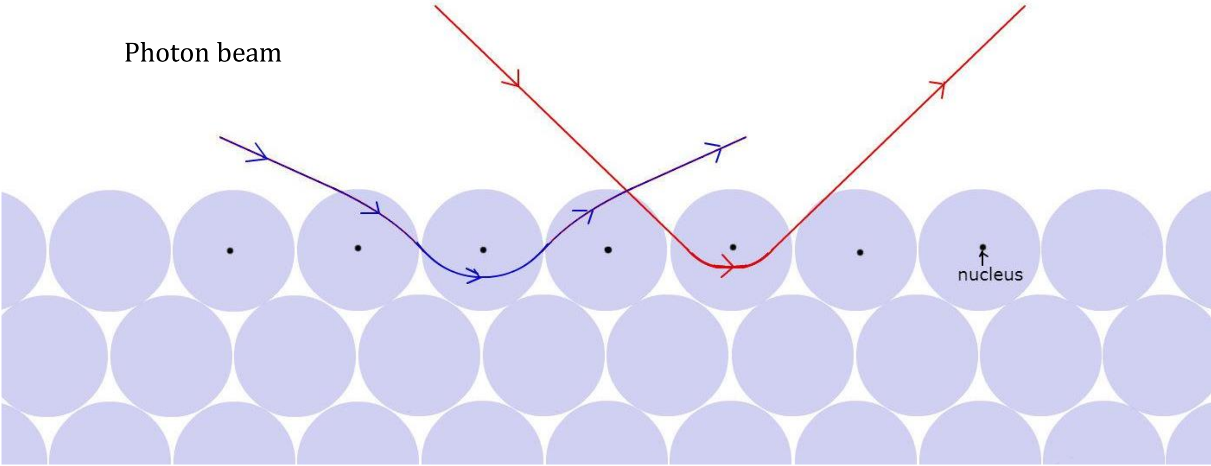

Figure 3.16 –Reflection of photons from surface

As seen in Figure 3.16, photons going to the surface from different angles interact with electrons electro statically as in Thomson scattering and reflect from the surface at the angle they come from. But this phenomenon looks like photons hitting the surface and reflecting. If the angle increases between the photons direction and the surface, the path of the photons changes (see Figure 3.17).

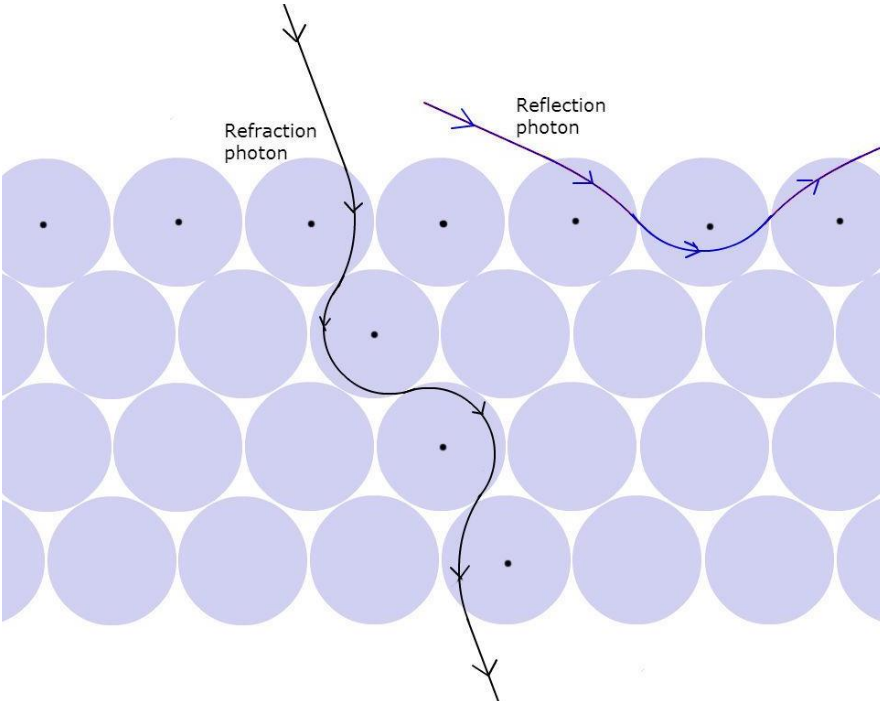

Figure 3.17 –Reflection and refraction of photons.

As seen in Figure 3.17, In refraction events, photons pass from one atom to another by following circular paths and their path becomes longer. But for an observer, photons appear to be slowing down. In fact, the speed of the photon does not change.

We mentioned that electrons also oscillate under the effect of electrostatic force. In a refraction event, photons attract electrons while travelling around the atoms and causing the electrons to oscillate (see Figure 3.18).

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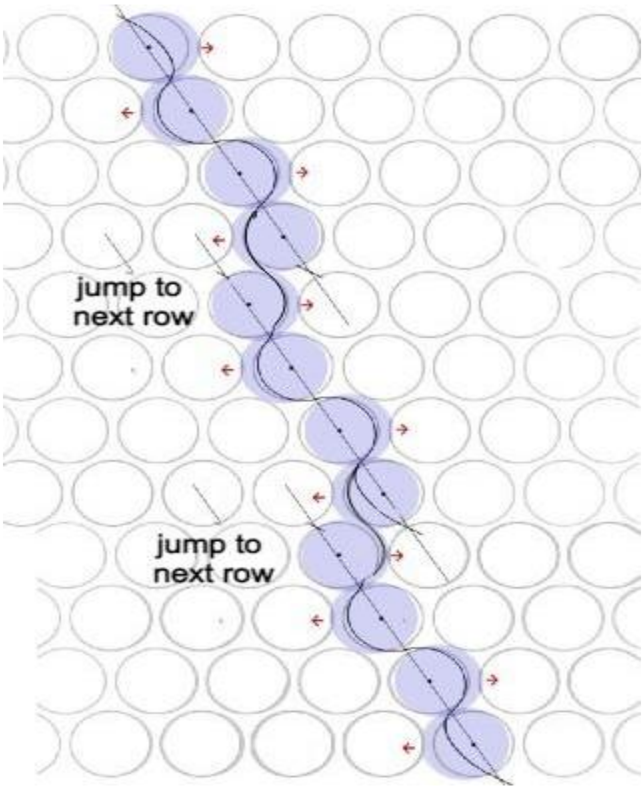

Figure 3.18 –Oscillating electrons

When the oscillation of electrons increases, the photons jump to the next row. During the oscillation, the electron to which the photon is attached, approaches the electron in the next row. The photon jumps to the electron of the next row with the effect of the oscillation and electrostatic forces between electron and photon (see Figure 3.19).

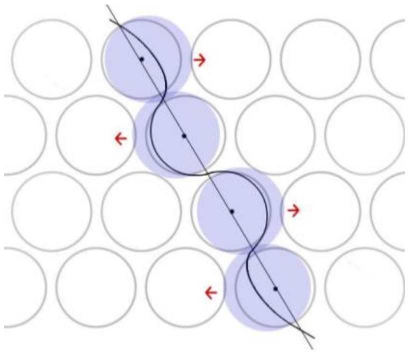

Figure 3.19 –Jump of photons to next atom row.

Since each material has different electron bonds, electron oscillations are different in each material. Therefore, After how many atoms, photons will jump to the next row depends on the structure of the matter. That's why, we see a different angle of refraction in each material. As a result, we will see refraction of light in transparent material like water or glass (see Figure 3.20).

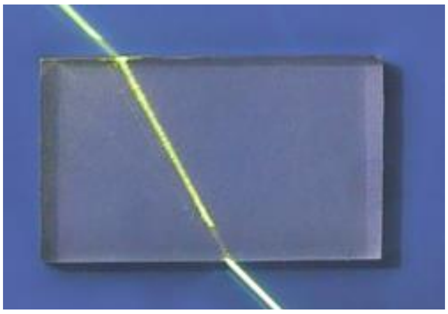

Figure 3.20 –Refraction of light

E. Photon Structure and Electromagnetic Wave

In Figure 3.21, An oscillating electric dipole antenna is shown. Each terminal of AC source is connected to a straight conductor; the two conductors comprise the antenna. As the voltage across the source oscillates, the charges on the two conductors also oscillate. Any charge or current distribution that oscillates sinusoidally with time, such as the oscillating point charge in Figure 3.21, produces electromagnetic waves (Physicsmax.com, 2013).

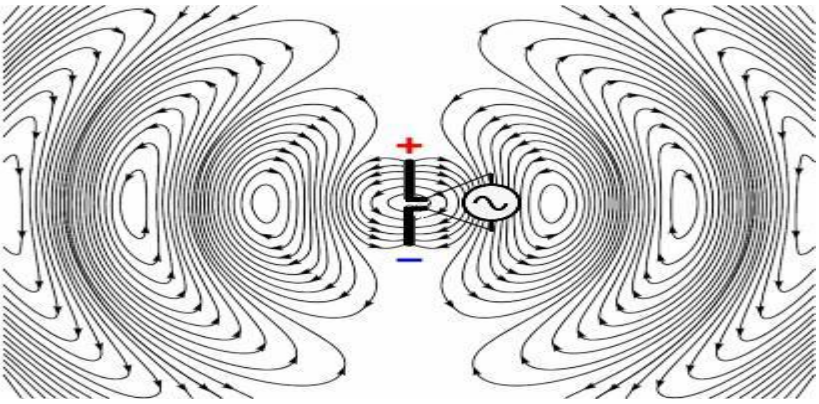

Figure 3.21 - Oscillating electric dipole antenna

If we think of a photon as a dipole particle, it will be a nanoscale antenna with positive and negative charge. If the photon starts to spin around the z axis as it travels (see Fig. 3.22), the positive and negative charges will shift (see Figure 3.23). Because of shifting, charged particles will start oscillating like in Figure 3.21. This will cause electromagnetic waves behind the photon (see Figure 3.23). Because waves and photon travel at the speed of light, we will not see waves in front of photon.

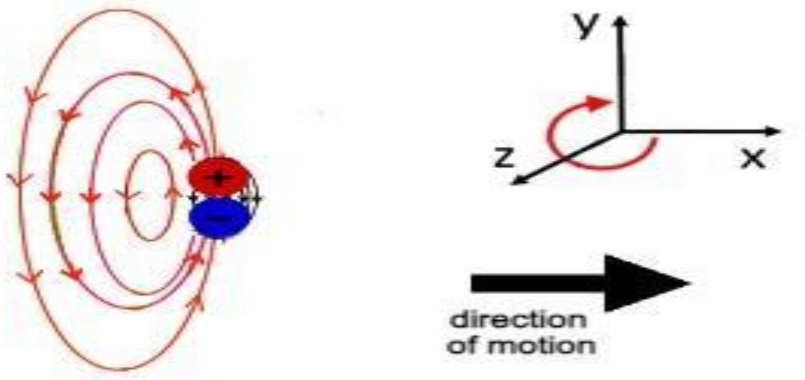

Figure 3.22 - Spinning and travelling photon

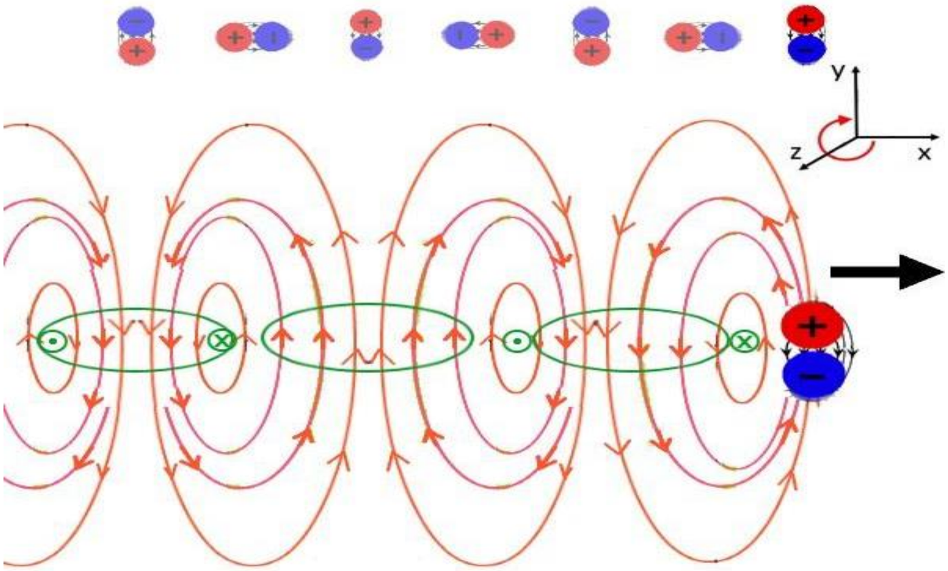

Figure 3.23 - Electromagnetic waves behind the photon. Red electric, green magnetic waves

Briefly, a dipole photon is a nanoscale antenna which moves at the speed of light. When travelling, it emits electromagnetic waves.

In section 2.3, We have mentioned that, if the charge value of **q** increases, the attraction force between positive and negative charged particles increases and the particles come closer to each other. So the size of the dipole photon decreases and spin frequency increases (see Figure 3.24). Charge value of dipole particles is related to the energy of the photon, energy of the photon is related to the frequency of electromagnetic waves. That's why, when energy increases, frequency also increases.

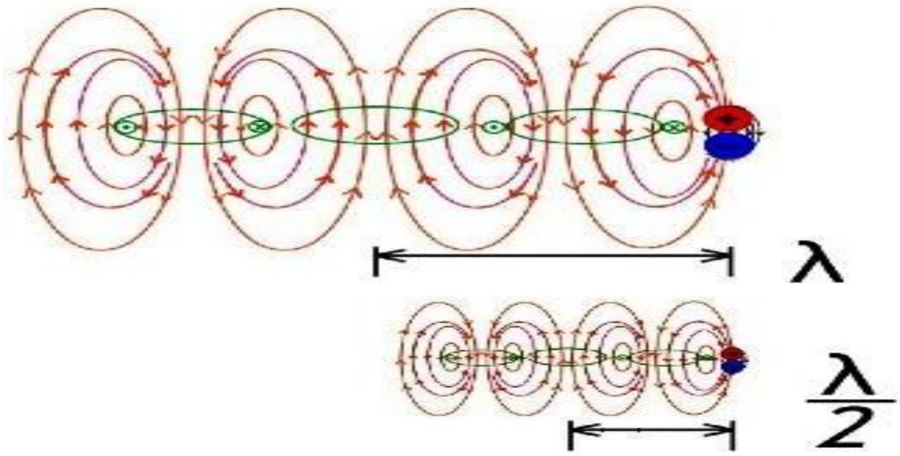

Figure 3.24 - Two photons with different wavelength and frequency.

CHAPTER IV

CONCLUSION

When we think of the photon as a dipole particle, all the events explained by the wave and particle model can be explained. There is no need for two different models. Therefore, it would not be wrong to say that light is a dipole particle.

The questions, "Why do dipole particles travel at a speed of 300,000km/s?" and "Why spin on the z-axis?" will be the topic of the next article. In order to explain it, first we must understand what is energy, mass and charge?

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