Geometric Origin of Photon Wave Properties

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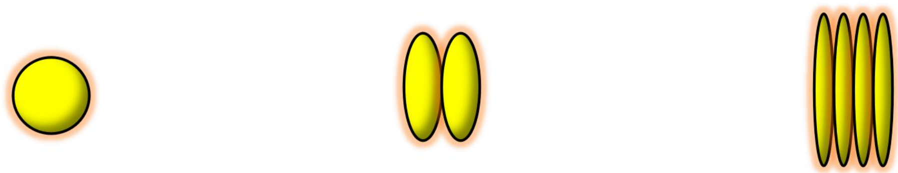
Abstract

In this paper, we propose a geometric ontology for the photon and demonstrate its capacity to explain the wave properties of light. Specifically, we discuss the nature of time and wave-particle duality. Also, we show how the geometric characteristics of photons naturally give rise to their frequency and amplitude.

Geometry of Photons

As we introduced in the article "How the Universe Works" (Liu, 2026), if everything in the universe, including the vacuum, is composed of "dots" (an imaginary basic unit that, regardless of its specific shape, always behaves like a "dot" in a continuous existence), then photons are essentially dots with a single-directional high density. In other words, rather than a particle, a photon is a series of one-way, high-density dots packed in a "fixed-length straight string". What is measured is not the energy of a photon, but the number of dots that it contains.



"Photon A" (1 dot)   Photon B (2 "photon dots")   Photon C (4 "photon dots")

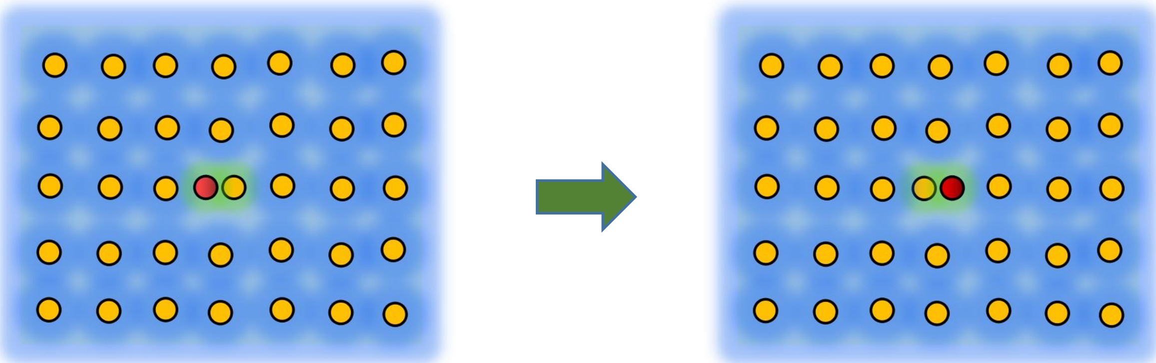
Photons are essentially multiple dots compressed into the length of a single dot. As demonstrated above, "Photon A" consists of one dot, which is essentially equivalent to a **vacuum dot**. Photon B is formed by squeezing two dots together into the length of a single dot. Photon C is formed by squeezing four dots together into the length of a single dot. Please note that although the dots are compressed, their "volume" remains unchanged. Therefore, they are actually pressed from a sphere into an oblate spheroid.

***The "volume" here can be understood as the range of "disturbance effect" caused by the compression of dots in the direction perpendicular to their direction of propagation/compression. This effect can be observed along the propagation path and can be likened to the disturbance caused by a sphere flattened into an oblate spheroid while its volume remains constant.*

Before explaining the wave nature of photons, we need to clarify two issues: what the essence of time is and what the speed of light is.

The Nature of Time

We assume that the dot is the basic unit of all existence in the universe, including the vacuum. Therefore, the flow of time is necessarily marked by the changes in the positions/states of the dots. Dots serve as the measure of time. Any difference between two time points must correspond to a difference in the positions of the dots at those time points. (If the positions and states of all dots in the universe are identical at two time points, then these two time points are essentially the same time point.) In other words, the essence of time is the positional change of all the dots in the universe. For instance, the precise moment of 2:56:00 a.m. on March 16, 2026, represents the totality of the exact positions and states of all dots in the universe at that instant.



"This Moment" "The Next Moment"

Therefore, the smallest difference between two moments (the true **minimum unit of time**) is the difference in the position of **a single dot**. In other words, theoretically, the sign that the universe transitions from "this moment" to "the next moment" is the appearance of the first dot in the universe whose position has changed relative to its position at "this moment", even if all other dots in the universe remain unchanged. Moreover, if we pay attention to the changes of those two dots at the center of the two pictures, we will find that the reason for this change could either be that the positions of the two dots have changed, or that their states (red and yellow) have been swapped. However, in either case, the result is equivalent to a change in position. Therefore, for the convenience of discussion, we will uniformly refer to this as "position change," even though "state change" also occurs in many scenarios. (In addition, a "state change" is essentially the cumulative effect of "position changes.")

"The Fastest Speed"

We have established that the essence of time is the change in the positions of dots. Then what is the fastest speed of motion in the universe (pure single motion, rather than compound movements such as the "expansion" of space)? **The fastest speed** of a single object's motion is the change in the position of a dot within the minimum time unit. In other words, the fastest speed of a single object in the universe is to move by the length of one dot (to pass one dot ahead) per minimum time unit.

As discussed earlier, the minimum time unit and the positional change of a single dot are essentially the same concept (which is precisely the origin of the definition of the minimum time unit). Therefore, this "fastest speed" cannot be surpassed because, if it could be (for example, if an object were to pass more than one dot per minimum time unit), it would imply that time can be further divided, which would contradict the definition of the "minimum unit of time."

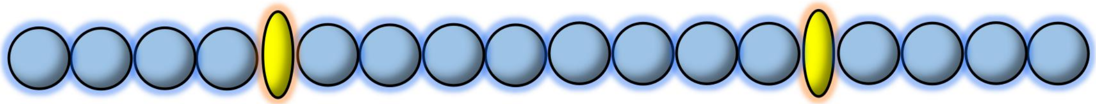
> ***Please note that although the discussion above may sound like circular reasoning, it is not actually the case, because from the perspective of dots, time can only be defined in this way. The only other point worth mentioning is that we still have an important factor that has not been discussed here: the* ***rotational effects*** *of dots or structures, such as spin. However, this belongs to the issue of directionality of time and does not affect the definition of "the fastest speed" or "the minimum unit of time." Therefore, to better focus on the main topic, we will not discuss it here for now.*

The "Lengthened" Photons

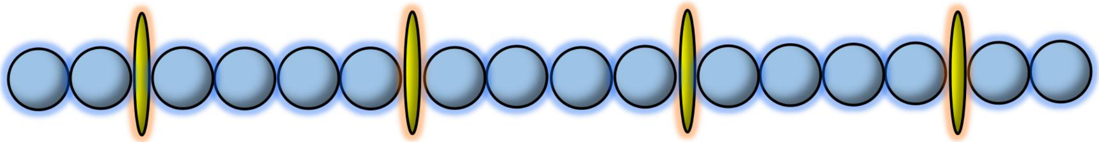
It is a fundamental postulate of modern physics that the speed of light in vacuum is the universe's upper velocity limit. If the speed of light is the fastest speed, it must follow the rule we discussed earlier: each movement can only pass over one dot at a time. The next question then arises: Can a photon (consisting of more than one dot) pass through a dot as a whole in one go, while still preserving the assumption that the speed of light in vacuum is the fastest speed?

Theoretically, it cannot. As we assumed at the beginning of the article, a photon is essentially a “string of dots”. It is itself a paradox if a string of dots can pass by a given dot within a minimum time unit. This violates the concept of the “minimum unit of time”, because among a series of dots, it is still possible to distinguish the order in which they pass by a marked dot. This is essentially further dividing the “minimum time unit”, which is clearly prohibited. (Note that this prohibition applies only to the motion of a single object. In some cases, it may be permissible for the combined motion of multiple objects.)

Therefore, when a photon travels through vacuum, in order to maintain “the fastest speed” without violating the rule of the “minimum unit of time,” the dots composing the photon are separated by vacuum dots. In other words, the “photon string of dots” is “lengthened.”



Photon B (2 photon dots)



Photon C (4 photon dots)

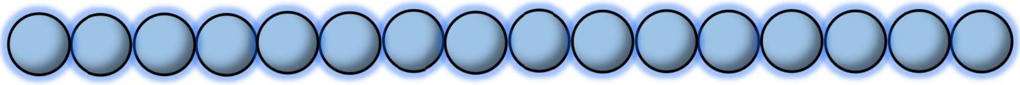
As demonstrated above, when photons travel through a vacuum, they are lengthened by vacuum dots to a certain length, with vacuum dots inserted between the photon dots, so that the dots of the string can pass by a given vacuum dot one after another without violating the rule of the minimum unit of time.

(Please note that the vacuum dots shown in the graph are merely a schematic representation and do not represent the actual quantity.)

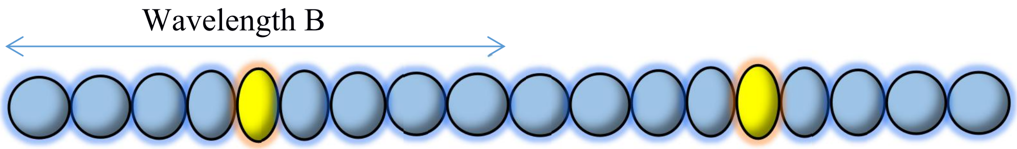
Wave-Particle Duality

In the previous text, we have already mentioned the particle nature and wave nature of photons. Now let us discuss them in detail.

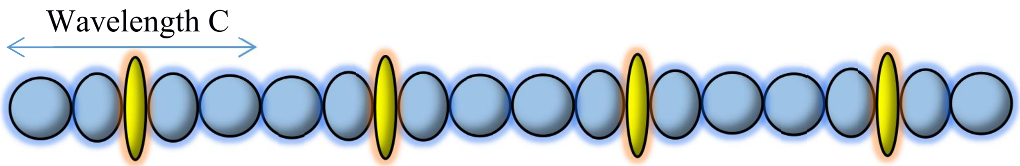
The Wave Nature of Photons



Vacuum dots (16 dots)



Photon B (2+16 dots)



Photon C (4 +16dots)

As shown in the figure above, the space is composed of dots. When a photon enters an area, it essentially squeezes more dots into that space. During propagation, the photon is “separated” into discrete dots (yellow). (In a stable space composed of a certain number of vacuum dots, no matter how many dots a photon contains, the speed at which it expands and the length it can expand to are always the same. This is because at “the fastest speed”, regardless of how many dots a photon contains, the range it can influence is always a fixed length; otherwise, it would violate the “Law of the Fastest Speed”.)

Meanwhile, when vacuum dots (blue) move along the “photon string”, they undergo varying degrees of “elastic deformation” due to the compression caused by the intrusion of photon dots (yellow). This dynamic elastic deformation causes periodic disturbances along the propagation path of a photon, which is the source of its wave nature.

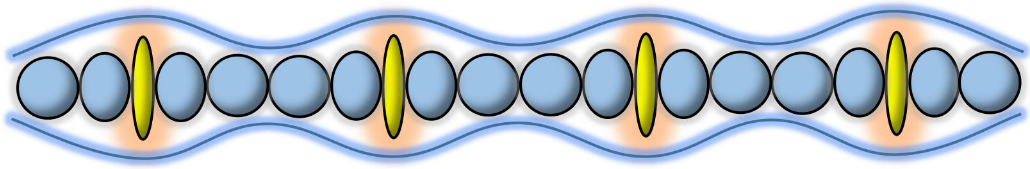
For example, as shown in the figures, suppose there is a fixed linear space consisting of 16 vacuum dots. When a photon enters this area, it squeezes photon dots into this linear space. As the photon dots (yellow) are separated by vacuum dots (blue), they are effectively "released" from the constraint of the photon (particle). As a result, the yellow dots tend to "bounce back" from an oblate spheroid to the original shape of a dot, which further flattens the adjacent vacuum dots into oblate spheroids. When Photon B enters this region, it brings 2 photon dots into the space. When Photon C enters this region, it brings 4 photon dots into the space. However, the space has a fixed length of only 16 dots. Therefore, as the photon dots are separated by vacuum dots, Photon B generates 2 waves and Photon C generates 4 waves. Please note that in the same vacuum region, the "lengths" of all photons (such as Photon B and Photon C) are the same in three respects. **First, their lengths as particles (the length of a photon) are the same. Second, their lengths as waves are the same. Third, when measured by the sum of the lengths of the photon dots in the waves (the total length of the separated yellow dots), all photons have the same value.**

Moreover, from the figures one can see that the wavelength of a photon equals the distance between its two photon dots (yellow). For example, as shown in the figures, the wavelength of Photon B is 8 dots, while the wavelength of Photon C is 4 dots, even though the lengths of Photon B and Photon C are the same.

In addition, from the figures one can also see that, under the assumed accuracy or resolution, the smoothness of the light waves of Photon B is significantly higher than that of Photon C. In other words, the wave nature of low-frequency light is more pronounced than that of high-frequency light. This is because there are more compressed vacuum dots (blue) between the photon dots (yellow) in a low-frequency light wave than in a high-frequency light wave.

<u>Single-Slit Diffraction</u>

Now, let us briefly discuss how single-slit diffraction can be interpreted within our model.

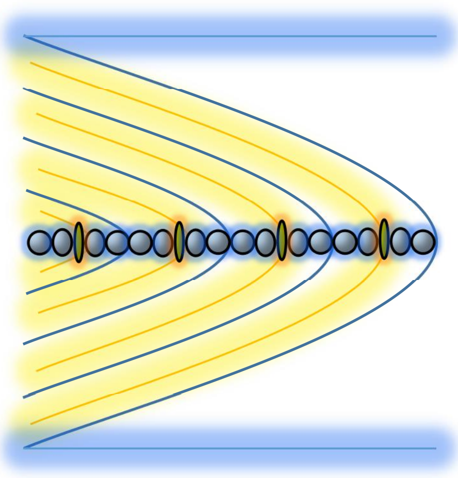


Photon C (4 +16 dots)

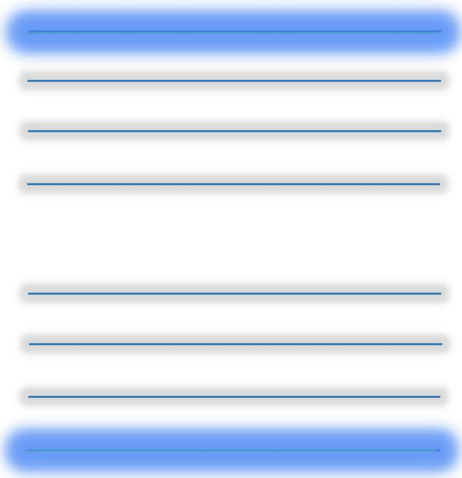
The propagation of a photon generates paths in the background space through the periodic disturbance caused by the "wave of photon". As shown above, the dots that form the wave peaks (yellow) generate a greater vertical disturbance range, thus squeezing the surrounding vacuum dots more strongly. As a result, the arrangement of these vacuum dots becomes more tightly compressed (through deformation). The dots that form the wave troughs, due to their smaller vertical disturbance range, exert a weaker squeeze on the surrounding vacuum dots. Consequently, the arrangement of these vacuum dots is more relaxed. As the photon propagates, it periodically forms "tight" and "relaxed" arrangements of the corresponding vacuum dots, which generate a series of paths in the background space.

Without any other intervention, these paths persist. They determine the layout of the background vacuum dots in the corresponding space, which further leads to "diffraction".

Scenario I:

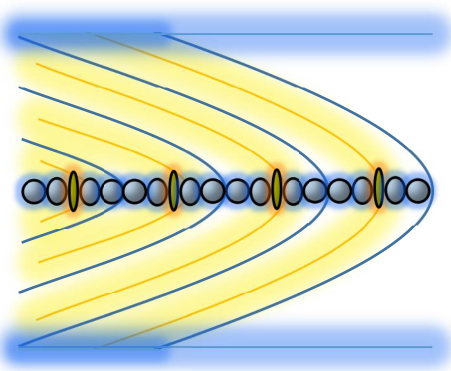


Photon C passing through Slit X



Slit X after Photon C

Scenario II:



Photon C passing through Slit Y

Slit Y after Photon C

As demonstrated above, we assume two scenarios. In Scenario I, when Photon C passes through Slit X, whose width is 4 times its wavelength (16 dots), its 4 photon dots (yellow) generate 7 paths. As a result, subsequent photons passing through the slit along these 7 paths form **7 bright fringes and 6 dark fringes** on the screen. (Each photon creates new paths, but when these paths are superimposed, they still follow this pattern.)

In Scenario II, when Photon C passes through Slit Y, whose width is 3 times its wavelength (12 dots), its 4 photon dots (yellow) generate 5 paths. (As shown in the figure, the "ripple" caused by the first yellow dot extends beyond the boundaries of Slit Y.) As a result, subsequent photons passing through the slit along these 5 paths form **5 bright fringes and 4 dark fringes** on the screen.

Now, let us verify these results using the standard single-slit diffraction formulas for minima and maxima.

For dark fringes (minima): $a \sin\theta = \pm k\lambda,\ k = 1,2,3...$

For bright fringes except the central maximum (secondary maxima): $a \sin\theta = \pm (k + \frac{1}{2})\lambda,\ k = 1,2,3...$

As $|\sin\theta| < 1$, we have: $k < \frac{a}{\lambda}$ (minima); $(k + \frac{1}{2}) < \frac{a}{\lambda}$ (secondary maxima)

*where a is the width of slit, λ is the wavelength of photon, k is the order of diffraction, and θ is the diffraction angle.

In Scenario I, $a = 4\lambda$. Thus, for minima, $k < 4 \rightarrow k = \pm 1, \pm 2, \pm 3$; for secondary maxima, $(k + \frac{1}{2}) < 4 \rightarrow k = \pm 1, \pm 2, \pm 3$. Therefore, **the total number of dark fringes is 6, and the total number of bright fringes is 7** (by adding the central maximum).

In Scenario II, $a = 3\lambda$. Thus, for minima, $k < 3 \rightarrow k = \pm 1, \pm 2$; for secondary maxima, $(k + \frac{1}{2}) < 3 \rightarrow k = \pm 1, \pm 2$. Therefore, **the total number of dark fringes is 4, and the total number of bright fringes is 5** (by adding the central maximum).

One can see that these results are consistent with our model.

In addition, it is worth noticing that, as shown in the figure, the bright fringes are formed by the peaks of the waves, while the dark fringes are formed by the troughs of the waves. This is contrary to common intuition. We will explain the reason in a future article when we discuss the principle of light propagation. (We will also further discuss the single-slit diffraction and double-slit interference phenomena in detail.)

<u>The Particle Nature of Photons</u>

Then why do photons also exhibit particle-like properties? This is because when the photon is detected, or when the experimental setup is capable of discerning the photon's path information, it essentially results in an instantaneous rearrangement of vacuum dots.

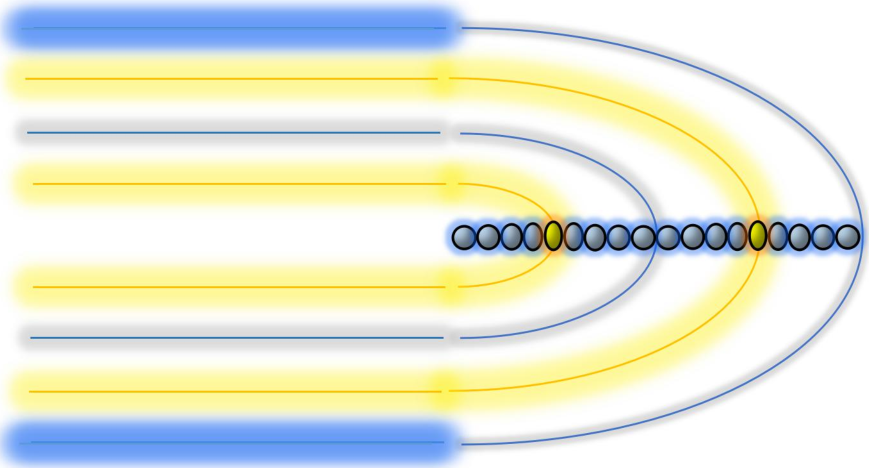


Figure 1: The instant background area after Photon B (without detection/intervention)

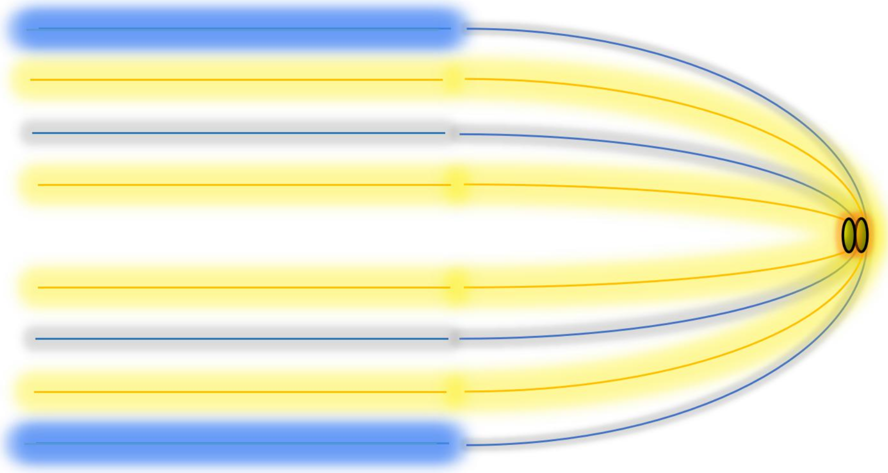


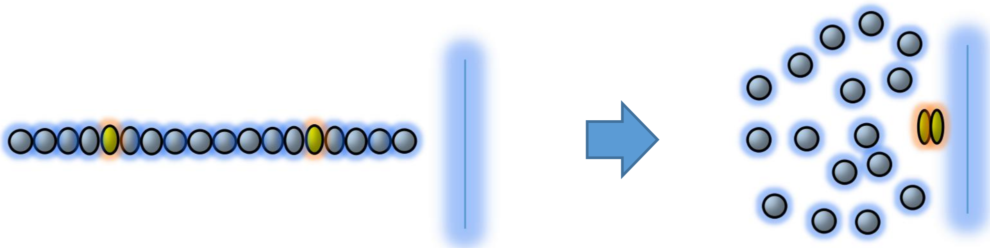
Figure 2: The instant background area after Photon B (with detection/intervention)

As demonstrated above, the shape of background vacuum dots is correlated with the form of the photon. In Figure 1, without detection, the photon is stretched apart by the vacuum dots, which causes a wave-like deformation of these dots. Each dot of the photon (yellow), as a peak of the wave, causes a ripple. As a result, the background vacuum dots are disturbed by these ripples and thus leave paths. The number of ripples is determined by the number of dots of the photon.

However, as shown in Figure 2, when the photon is detected, it returns to the size of one dot (particle). As a result, no matter how many dots it contains, all the ripples/paths are merged into one.

Why does a photon regain its particle nature upon detection? This is because both detecting the photon and detecting its path alter the original “force state” of the vacuum dots (blue) between the photon dots (yellow). The vacuum dots between photon dots were originally subjected to force only along the string of the photon (due to the compression of the photon dots). These vacuum dots are in a dynamic equilibrium state with the dots of the photon. However, when the photon is detected, this equilibrium state is disrupted. Therefore, these vacuum dots (blue) have an infinitely high probability of turning to other movement directions and thus detaching from the string of the photon (wave). This is the fundamental principle of the particle nature of photons.

The “particleization” that occurs when a photon collides with (or is absorbed by) an object and the “particleization” caused by detection share the same principle.



For example, as demonstrated above, when the "wave of photon" comes into contact with the wall, the vacuum dots (blue) are squeezed out of the track, return to their original shape, and are returned to the vacuum, while only the original photon dots (yellow) remain. For the wall, it receives a photon (a continuous series of photon dots), rather than a light wave (discrete photon dots).

For a photon, any detection is essentially a collision. From the perspective of time, when a photon is detected, all its dots (yellow) are detected at the same time. This is because when the detection occurs, all the vacuum dots (blue) are gone. There are no vacuum dots to separate the photon dots (yellow). In other words, there is no temporal or spatial gap between the dots of the photon. The photon switches from a wave state to a particle state.

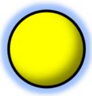
Therefore, when we detect it, no matter how many dots it contains, a photon is a photon. Any interference will alter the force structure of the photon, causing the vacuum dots (blue) between the dots of the photon (yellow) to move in other directions. Then the photon turns from discontinuous dots (wave) to continuous dots (particle). Meanwhile, the length of the photon (as wave) "shrinks back" to the length of one dot (as particle).

Then why does the detection of the photon's path also affect the structure of the photon itself? This is because there is a "rigid connection" between the photon and its path. This rigid connection does not involve any changes in the position of dots along the path. (Only at the moment of detection will the vacuum dots located between the dots of the photon undergo a one-time displacement.) Therefore, this process takes almost no time. (As we discussed earlier, time is the effect of the positional change of dots. The whole process takes only a moment because each *vacuum dot undergoes a one-time displacement simultaneously. It may take extra time for the vacuum dots to rearrange to another equilibrium state. For the photon, however, there is no time gap between its dots upon detection.) This "rigid connection" issue is related to the essence of the ripple (as we mentioned earlier). We will explain it in a future article.*

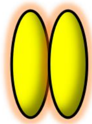
With the wave-like and particle-like behaviors of photons now established, we can explain the frequency and amplitude of light from a purely geometric perspective.

Frequency

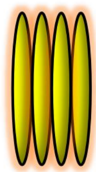
As we discussed earlier, whether in wave form or particle form, the lengths of all photons are the same.



"Photon A" (vacuum dot)



Photon B (particle)



Photon C (particle)

"Photon A" (wave of vacuum/space)

Photon B (wave)

Photon C (wave)

As demonstrated above, the essence of the frequency of a photon is the number of dots of the photon (yellow). Therefore, our detection of frequency is essentially a count of the number of ripples caused by the dots of the photon (yellow).

Assuming we have a detector that can count the passing photon dots (yellow, wave peaks), we would obtain the following results: when "Photon A" passes by, the count is 1 dot; when Photon B passes by, the count is 2 dots; and when Photon C passes by, the count is 4 dots. ("Photon A" as a wave is essentially one extra vacuum dot squeezed into a space composed of vacuum dots. Theoretically, "Photon A" is almost undetectable. Here we are using “Photon A”/vacuum dot as the benchmark for the calculation.)

The origin of the frequency (and wavelength) is the number of dots (yellow) contained in a single photon. The length of a photon is the diameter of a dot, and a dot is the most fundamental unit of existence. Therefore, in any beam of light, regardless of the number of photons, these photons cannot “overlap” with each other.

Thus, when a beam of light passes by and we count the yellow dots that pass, our count is always equal to the number of dots when the individual photons are arranged end-to-end in a straight line. In other words, the frequency of the light is only related to the number of dots contained in a single photon. At the same frequency, the difference in the number/density of photons (energy and light intensity) is reflected in the amplitude.

For example, if there are three light beams A, B, and C, composed of “Photon A”, Photon B, and Photon C respectively. When we measure the frequency of “Beam A” as m, then the frequency of Beam B is 2m, and the frequency of Beam C is 4m.

(Please note that “m” represents the artificial counting of “1”, the actual base frequency.)

	Composition	Number of Dots Per Photon	Frequency
“Beam A”	“Photon A”	1	m
Beam B	Photon B	2	2m
Beam C	Photon C	4	4m

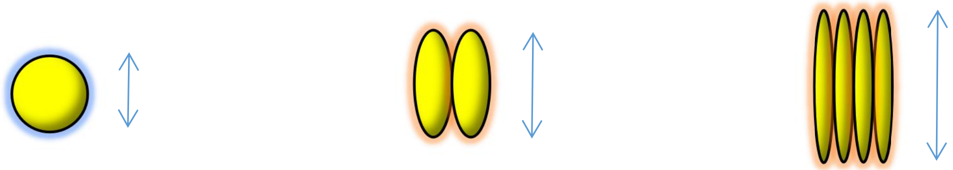
Amplitude

We assume the diameter of “Photon A” is 1. The volume of “Photon A” would be $\frac{\pi}{6}$.

In Photon B and C, **the volume of a dot remains the same**. As a result, the volume of Photon B would be $\frac{\pi}{3}$ and the volume of Photon C would be $\frac{2}{3}\pi$. Then we can calculate the “width” (the major axis/equatorial diameter of the “squeezed dots”) of B and C:

The width of Photon B is: $\sqrt{2}$

The width of Photon C is: 2



"Photon A" (width: 1) Photon B (width: $\sqrt{2}$) Photon C (width: 2)

This width, the long axis diameter of the "squeezed dots", is the origin of the amplitude of light waves. From the calculation, we obtain the general formula for the width of a photon: $W = \sqrt{k}$, where k is the number of dots (yellow) a photon contains. One can see that k is essentially the frequency.

Now, let us use some examples to compare the results of the traditional formula with those of our geometric model. Suppose there are six beams:

Beam a, consisting of n "Photons A"

Beam b, consisting of 4n "Photons A"

Beam c, consisting of n Photons B

Beam d, consisting of 4n Photons B

Beam e, consisting of n Photons C

Beam f, consisting of 4n Photons C

Assuming that all other conditions are the same, we know that the relationship between light intensity (I), the number of photons (N) , and frequency (v), is as follows: $\mathrm{I} = \Phi \cdot h\mathrm{v}$, where the photon flux Φ is determined by the number of dots (N) and h is the Planck constant. Also, light intensity is proportional to the square of the amplitude (A): $\mathrm{I} \propto \mathrm{A}^2$.

Therefore: $A \propto \sqrt{\mathrm{N} \cdot \mathrm{v}}$

Taking the amplitude of Beam a as the reference amplitude $\mathrm{A_a}$, we have $\mathrm{A_a} = \sqrt{\mathrm{nm}}$, then:

$\mathrm{A_b} = 2\sqrt{\mathrm{nm}}$; $\mathrm{A_c} = \sqrt{2}\sqrt{\mathrm{nm}}$; $\mathrm{A_d} = 2\sqrt{2}\sqrt{\mathrm{nm}}$; $\mathrm{A_e} = 2\sqrt{\mathrm{nm}}$; $\mathrm{A_f} = 4\sqrt{\mathrm{nm}}$.

(please note that the essence of m is actually "1", the frequency of "Photon A")

We can get that $A_a : A_b : A_c : A_d : A_e : A_f = 1 : 2 : \sqrt{2} : 2\sqrt{2} : 2 : 4$

Now let us redo this calculation from a geometric perspective.

As we discussed earlier, from a geometric perspective, the amplitude is actually the effect of the "width" of the photon dots (yellow).

As we introduced, the width of a photon is $\sqrt{k}$, where k is the number of dots (yellow) the photon contains.

The number of photons on the cross-section of the beam is determined by N. The beam can be approximately regarded as a cylinder. We have already assumed that the "length" of all the beams listed above is the same fixed value. Therefore, to calculate the width, after removing the constant, we get:

$W_{beam} \propto \sqrt{N} \cdot \sqrt{k}$

Taking the "width" of Beam a as the "reference width" W_a, we have $W_a = \sqrt{n} \cdot \sqrt{m} = \sqrt{nm}$, then:

$W_b = 2\sqrt{nm}$; $W_c = \sqrt{2}\sqrt{nm}$; $W_d = 2\sqrt{2}\sqrt{nm}$; $W_e = 2\sqrt{nm}$; $W_f = 4\sqrt{nm}$

We can get that $W_a : W_b : W_c : W_d : W_e : W_f = 1 : 2 : \sqrt{2} : 2\sqrt{2} : 2 : 4$

To summarize the results above, we get:

Beam	Composition	Number of Photons	Frequency	"Width"	Amplitude
a	"Photon A"	n	m	1	1
b	"Photon A"	4n	m	2	2
c	Photon B	n	2m	$\sqrt{2}$	$\sqrt{2}$
d	Photon B	4n	2m	$2\sqrt{2}$	$2\sqrt{2}$
e	Photon C	n	4m	2	2
f	Photon C	4n	4m	4	4

From the table, one can see that the width and the amplitude are essentially the same thing. As discussed earlier, the frequency (v) is essentially the number of dots of a photon (k). Thus, we can also get $W \propto \sqrt{N} \cdot \sqrt{k} \propto \sqrt{N \cdot v} \propto A$. This model can perfectly explain the frequency and amplitude of light from a purely geometric perspective.

Moreover, this geometric approach explains why long waves are more capable of passing through non-conductive materials than short waves. Compared to short-wave photons (high frequency), long-wave photons (low frequency) are "narrower" and have fewer photon dots (yellow), making them less likely to collide with the substance. (For the same reason, in non-vacuum media, low-frequency light travels faster than high-frequency light.)

Also, our geometric model explains why two low-energy photons are more likely to "pass through" each other when they encounter, because they are "narrower". When high-energy photons meet, there is a greater chance of them colliding with each other, because they are "wider".

Conclusion

In our geometric model, both the particle nature and the wave nature of photons can be explained. Properties of light such as wavelength, frequency, amplitude, and intensity are all consistently described within this framework. Moreover, the geometric structure of the photon naturally explains why a high-energy photon can split into multiple low-energy photons, since the photon itself is composed of multiple dots.

In subsequent articles, we will interpret the principle of photon propagation based on this geometric model. We will elaborate on a series of experiments, including the double-slit interference experiment (as well as delayed-choice and quantum erasure experiments). Furthermore, within our theoretical framework, we will explain the mechanisms of electron–positron pair production in photon–photon collisions, particle spin, quantum entanglement, and non-locality.

Reference:

Liu, J. (2026). *How the Universe Works.* ResearchGate. https://www.researchgate.net/publication/401044345_How_The_Universe_Works