Explanation of Quantum Phenomena with a New Model of Photon and Electron Emission, Propagation and Absorption

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Abstract

The puzzles of quantum mechanics are: 1. what is the medium for the photon and for the electron wave? i.e. *what* is waving? 2. particle interference pattern 3. observer effect. 4. entanglement. In Quantum Erasure and Double-Slit experiments, how does the emitter know to direct the photon two both slits or only to one slit? And how does the detector know where to detect the photons to form an interference pattern and not a bell-shaped (Gaussian) pattern or vice versa? This paper proposes a few, closely related, simple and subtle laws of nature governing quantum phenomena. Some of the findings in this paper are: 1. A photon is emitted in two steps: the creation of photon path and the emission of the photon 2. Although (almost) all of the energy of the photon is localized in space, the photon extends to infinity. An extremely small energy of the photon, which we call the 'precursor wave' in this paper, extends to infinity. The instant the photon is emitted, its precursor wave creates a path to infinity; it appears instantaneously in all its path to infinity, with infinitely small energy density. The precursor wave serves as the 'highway' for the propagation of the main energy packet. However, to conserve the principle of causality, we assume that the tip of the photon propagates at a speed billions times the speed of light. Thus, there are two speeds associated with the photon: the speed we know as *c* and the speed at which the photon length increases. 2. A photon will be emitted only towards an absorber. A photon is emitted by the interaction of the emitter and a detector. It is obvious that a photon will not be emitted if there is no emitter. Nor will a photon be emitted if there is no detector . Once a photon is emitted, however, it exists objectively, autonomously. The photon is emitted only after its path is determined by the interaction of the emitter and the absorber, at the instant of emission. 3. The photon energy will be concentrated where there is higher wave amplitude, i.e higher intensity of oscillation of electric and magnetic fields. This results in 'dragging' of the electromagnetic energy by the wave, hence eliminating the need for any medium. It is also proposed that single photon interference is a quantum phenomenon whereas two photon interference is a classical phenomenon. Similar laws hold for the electron. The 'medium' for the electron wave is the electron (the electron mass density field) itself. Where there is higher intensity of electron wave/oscillation, there will be higher electron mass density. This means that the electron wave 'drags' the electron with itself. Therefore, no exotic 'medium' is required for the photon and for the electron wave.

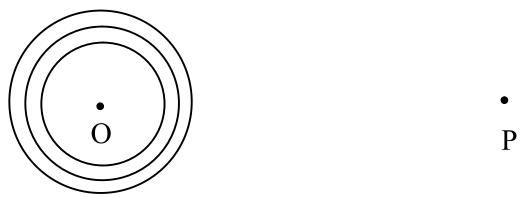
Introduction

In my previous paper [1], I proposed a theory to explain the interference patterns in photon and electron Double-Slit experiments. A simple yet subtle law of nature of photons and electron waves was proposed. However, the theory was not complete. For example, the Quantum Erasure (‘Which-Way’) experiments were not addressed. The concept of 'wave collapse' is also counter intuitive. In this paper a more complete form of the previous theory[1] is presented as an alternative to the Copenhagen interpretation.

The Double-Slit experiment - A new model for the photon and electron wave

The complete explanation for the Double-Slit experiment will be proposed next. We first review the previous theory [1] and present the modified form.

Ordinary waves such as water waves, sound, string and solid waves are travelling disturbances of their material media. If we drop a stone into a pond, a packet of circular water waves will form and travel radially outwards, with its center O at a point where the stone was dropped. Let us see what happens at a certain point P some distance away from the origin of the wave.



Before the arrival of the wave packet, the water is standing still at point P. As the wave arrives, the water molecules start to oscillate vertically. After the wave packet has passed away, the water molecules become standing still again. The wave (the oscillation) disappears from point P.

Here we note a seemingly trivial yet key idea:
Disappearance of the water wave (oscillation) from point P doesn't mean disappearance of water molecules from point P. This idea is the basis of the distinction between ordinary waves and quantum waves (the photon, the electron wave).

At first consider the electron as a continuous field of electron mass (and charge) density field distributed continuously in space, not as a point particle. With this picture, the electron is analogous to the pond water example discussed above. Assume that a wave is created somehow in the electron 'pond', analogous to the water wave. If we assume direct analogy between the electron wave and the water wave, the electron would be standing still at point P before the arrival of the wave, it oscillates (longitudinal or transverse) as the wave arrives and becomes standing still again after the wave passes away. But from our ordinary experience of motion of particles we know that there will be no particle at a point until the particle arrives and after the particle has already passed through the point. The particle is detected at a point only when it arrives at that point.

Therefore, we need to modify this direct analogy for the electron as follows:

There will be no electron (electron field) at point P before the arrival of the electron wave and after the electron wave has passed away. The electron field (electron mass and charge density field) disappears from point P with the disappearance of the wave. Unlike the water wave, the medium for the electron wave, which is the electron mass density field itself, exists at a point only when the wave (oscillation) exists (non-zero) at that point. This means that the electron wave drags the electron (and the electron medium) with itself. Where and when there is no electron wave (oscillation), i.e. where the amplitude of the wave is zero, there will be no electron; the electron mass density will be zero there.

The puzzle can now be resolved:

“If an electron is a wave, then what is the medium for the electron wave? What is waving ?”

The electron is both the medium and the wave. The medium for the electron wave is the electron mass density field itself. No exotic medium is required. (The same is to the photon- to be discussed later).

The electron interference pattern in the single electron Double-Slit experiment can be explained as follows. As the electron is fired towards the plate with two slits, it propagates as a wave packet. The wave fronts meet the two slits and pass through the slits. On the other side of the plate, the two slits act as two sources. Along the detector screen, the waves from the two slits interfere with continuously varying degrees of constructive and destructive interference. At some points, the waves may interfere completely constructively, and at some other points completely destructively. At points of complete destructive interference, the amplitude of the wave (the intensity of electron oscillation) will be zero. According to the new theory introduced here, the mass density of the electron will be zero at these points. At points of complete constructive interference, the amplitude of the wave will be maximum (the intensity of the oscillation will be maximum) and hence the mass density of the electron will be maximum at those points.

As the electron is a particle, it can be detected at only one point on the screen. At this point it is logical to assume that the electron will be more likely to be detected at points of higher electron mass density and less likely to be detected at points of less electron mass density. Therefore, the electron will never be detected at points where the amplitude of the wave is zero, i.e. at points of complete destructive interference. Therefore, the probability that the electron will be detected at a certain point on the detector screen is directly proportional to the mass density of the electron at that point. Unlike the ‘probability’ in the Copenhagen interpretation, the ‘probability’ here is in accordance with the principles of causality and determinism. At the instant of the detection at a certain point, the electron field ‘collapses’ to that point.

Next the explanation for the photon Double-Slit experiment will be presented.

The explanation for the interference pattern in Double-Slit experiment for the photon is similar to that of the electron, but with ‘photon energy density’ instead of ‘electron mass (energy?) density’.

Let us consider the pond water wave analogy again. If we take direct analogy between a water wave and a photon, then we observe a static electric and magnetic field at point P before arrival of the photon wave, then a time varying electric and magnetic field as the photon arrives, and a static electric and magnetic field again after the photon has passed away.

This direct analogy is wrong and is to be modified for the photon as follows. There will be no static electric and magnetic fields at point P before the arrival of the photon, there will be time varying electric and magnetic fields as the photon arrives and there will be no static electric and magnetic fields after the photon has already passed through point P.

However, from the new model of the photon that is going to be proposed shortly, time varying electric and magnetic fields exist, theoretically, before the arrival of the main photon energy packet. The photon extends to infinity according to the new model.

A more detailed discussion is found in my previous paper [1] and I recommend the reader to read it.

The above explanation of the Double-Slit experiments is compelling, especially when considering the counterintuitive Copenhagen interpretation. The new theory is self evident from its simplicity and subtlety.

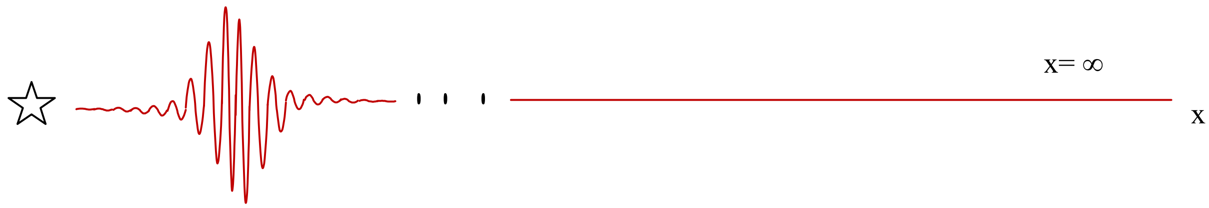
There are, however, some problems with the new theory that show it isn't in its complete, final form yet. The idea of 'collapse' is still counterintuitive. There are also some complications. For example, why should we assume that the wave front passes only through the slits? Part of the photon or the electron wave can also be thought as reflecting back from the wall of the plate, thus creating a problem that only part of the photon may pass to the other side of the plate. The phenomena of Quantum Entanglement and Quantum Erasure cannot be explained by the new theory.

The attempt to explain these phenomena and to solve the above problems of the new theory[1] resulted in a need to review and change the existing model of the photon.

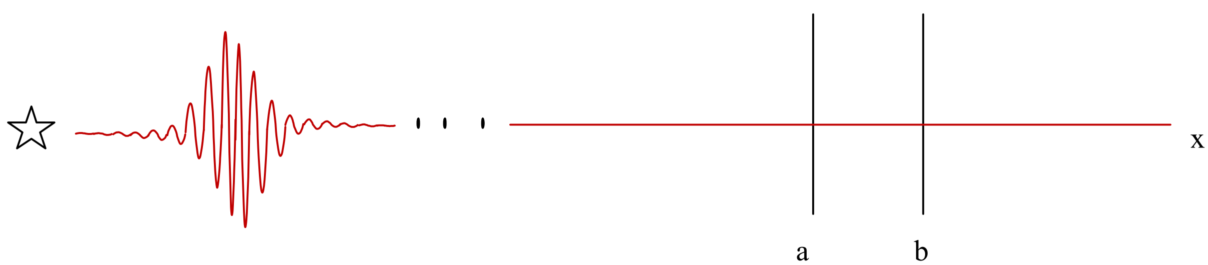
Photon extending to infinity

According to the existing model, a photon is considered to be a spatially localized propagating electromagnetic energy. The new model is as follows:

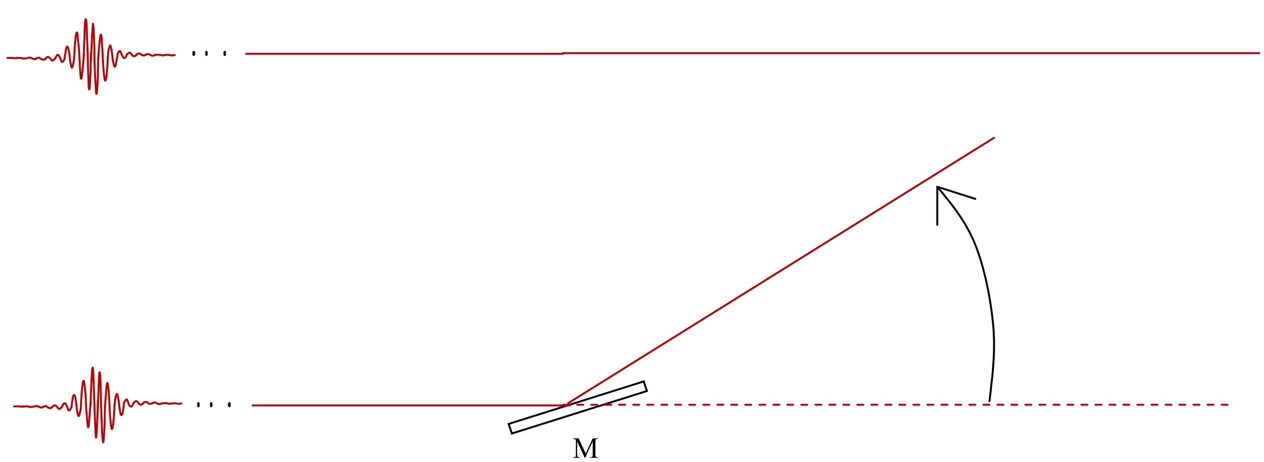
A photon is a spatially localized packet of electromagnetic energy. However, the photon is not completely localized. The photon is both a localized and an extended entity. Almost all of the energy of the photon, say 99.99…9%, is contained in the localized main energy packet and an extremely small amount of energy, say 0.00…1% , is contained in its extended part, preceding the main packet. We call this wave a precursor wave or precursor photon from now on. The photon, in principle, extends to infinity, with energy density approaching zero at infinity. At the instance a photon is emitted, it 'appears' simultaneously in all points to infinity.



Despite its infinite length, however, the photon acts as an entity. Such a view of the photon may give rise to questions. For example, what happens if part of a photon (between points a and b) that is one light year away is absorbed? In principle, if part of a photon energy is absorbed (however extremely small) at some point, the frequency (and wavelength) of the whole photon changes simultaneously, according to Planck's relation (E= h f), at all points to infinity.



Consider also another possible problem. Assume that initially the photon is emitted and it is extended to infinity as shown below.



Suppose that a mirror M is suddenly placed in the path of the photon. Now the photon will reflect as shown. But what happens to part of the photon energy that has already passed past the mirror location? Will it be 'detached' from the main photon? No. Not only the incoming ray, but the ray that already passed the mirror position before the introduction of the mirror will deflect as shown, as if the mirror was there before its placement in the path of the photon. A photon can never be divided. It is impossible to trap part of a photon, for example, in a mirror box.

Another question will be regarding the speed of light. If a photon appears at a point one light year away at the instant of its emission, does this mean that the speed of light is infinite? Then what is the speed of light which is known to be 300,000 Km/s ?

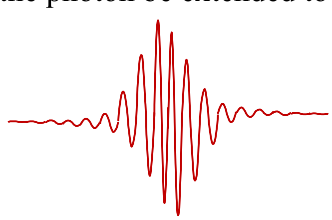
The speed of light we know as *c* is the speed with which the whole photon moves. Even though the photon appears instantaneously at a point one light year away at the instant of its emission, the energy density will be so extremely small there. It will be only after one year that the main energy packet (which contains 99.99…9% of the energy) arrives.

The infinitely small amount of energy in front of the main packet determines the path of the main packet. It forms the 'highway' for the main energy packet. The main energy packet follows it. Even though the photon extends to infinity, the photon remains intact during propagation. The photons frequency will change only if part of its energy is absorbed.

The assertion that the photon extends to infinity came from two facts and logic:

1. The Delayed Quantum Erasure experiment. No matter how far one detector and polarizer is from the source of the entangled photons, the interference pattern will be erased. With the conventional model of the photon we will face the puzzle: how does the photon know the presence of the polarizer before getting there?

2. If the photon energy density abruptly becomes zero at some point in front of the main energy packet (as shown below), then according to the new theory the photon cannot propagate because there is no 'high way' for it. The new theory requires that the precursor part of the photon be extended to infinity.

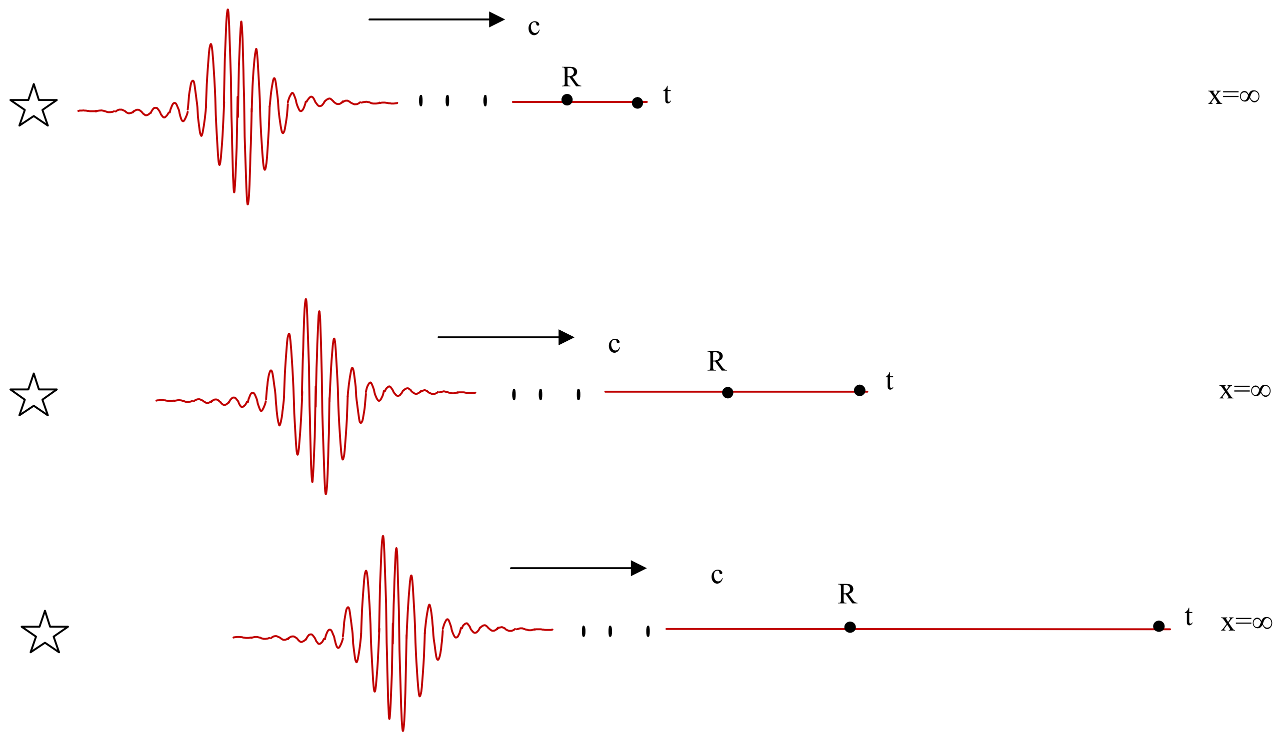


3. The model of infinite photon length eliminates the need for the counterintuitive 'wave collapse'

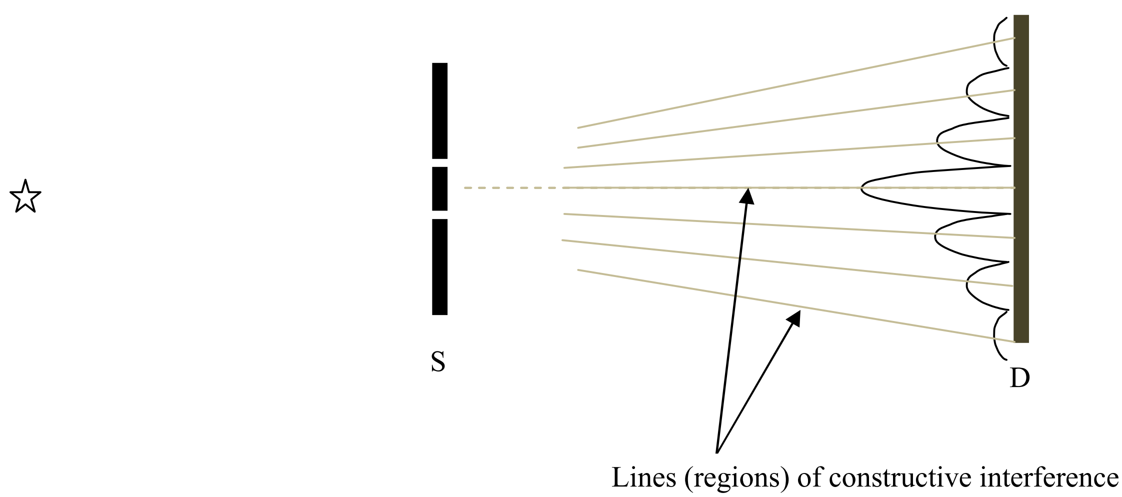
The tail of the photon is assumed to be finite, otherwise a complication (not discussed here) arises. This assertion is additionally supported by the fact that the photon moves only forward, hence does not need a 'high-way' in the backward direction,; therefore the photon does not need back ward extension to infinity.

The motion of the photon after its emission is shown as below. Note the motion of a reference phase point R on the photon.

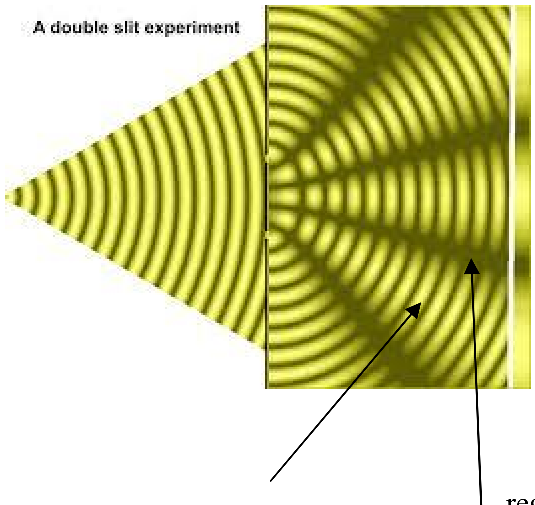
Note the two speeds associated with the photon in the diagram below. The progress of reference phase point R (also the progress of the packet) shows the speed we know as *c*. The tip t of the photon is also shown to propagate at a speed billions times *c*, hence increasing the length of the photon. Note that the two speeds are not shown to scale in the above diagram.

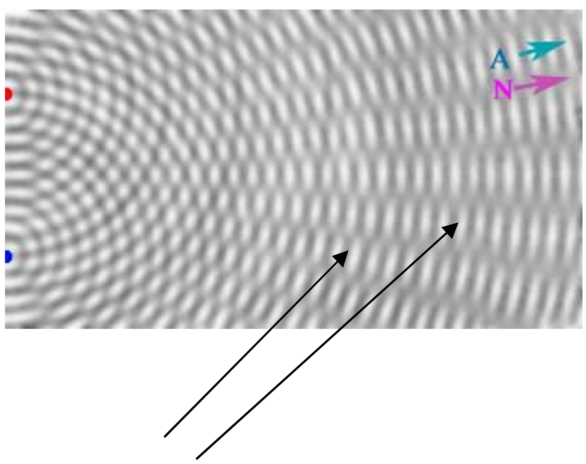


With this model of the photon, we can get a more intuitive and logical understanding of the Double-Slit experiments.



At the instant of emission, the photon appears instantaneously in all space between the source and the double-slit plate S and detector screen D. The energy of the photon is 99.99…9% in the vicinity of the emitting atom and only 0.00…1% in the extremely faint wave (precursor wave) preceding the main packet, just at the instant of emission. This wave forms an interference pattern, almost instantaneously at the instant of emission, in the space between the plate S and detector screen D.





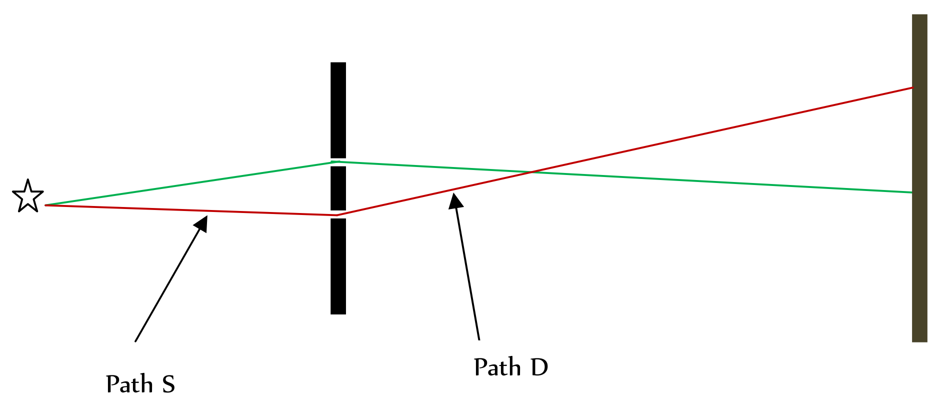
Some of the more probable paths of the photon (regions of constructive interference) . The photon path will collapse to one of these. In ordinary waves, these are simply regions of constructive interference and not the paths of the waves.

This interference pattern is only extremely brief (say billionths of a nanosecond ?) . It determines the path of the main energy packet of the photon. In the interference patterns in the figures above, paths to regions of constructive interference can be seen, representing the more probable paths of the photon. Note again that the formation of the interference pattern is almost an instantaneous phenomena, and it disappears once the photon path is established.

Now, we will see the evolution of *photon path*. At the brief instant of formation of the interference pattern, the entire wave 'collapses' to one line (path). The photon takes one of the infinitely many paths formed by the interference pattern. This is unlike ordinary waves, where the secondary waves from the two slits will not affect each other: for ordinary waves each wave from the two slits propagates independently. *This is a unique feature of quantum waves in which the path of the wave is governed by the interference pattern*. In ordinary waves, the secondary waves always move radially outwards from each slit. The lines seen in the pattern are only regions of constructive interference and the waves do not propagate along those lines. In the case of a photon (and electron wave), the path of the wave changes to follow one of the paths/ lines formed by the interference pattern. This means, unlike ordinary waves, the two slits combine to form a single source.

The photon takes only one of those paths. Higher probability is associated with paths formed by points of complete constructive interference. We can also see this as : the density of possible paths is higher along the line of complete constructive interference and no path exists along regions of complete destructive interference, i.e. points of zero wave amplitude. Note again that all this occurs instantaneously, at the instant of emission of the photon.

After the brief instant of photon path formation, two of the infinitely many possible paths of the photon can be as shown in the next figure. Only two possible paths (one in red, another in green) are shown in the figure. The photon can take only ONE path from the emitter to the detector. As the photon collapses to a single path in the space between the double-slit plate and the detector screen, it will also collapse accordingly to either slit, in the space between the photon source and the detector screen.



Which of the two slits the photon takes is fundamentally deterministic and causal. And which of the many possible paths the photon takes from a slit to the detector is also fundamentally deterministic and causal. These two paths should form a single continuous path from the source to the detector. It can be seen as predicting the path of a single atom in a gas that is in turbulence. The fundamental law governing the phenomena is already introduced in this paper : the photon energy will always propagate towards regions of higher intensity of oscillation, to regions of higher wave amplitude. This law, together with initial conditions, instantaneously determines the path of the photon. At the instant of emission, i.e. at the instant of light path formation, the vicinity of the emitting atom and the vicinity of the slit outlets can be seen as regions of highly turbulent gas flow. Once the two paths (the path from the source to one of the slits, and the path from that slit to the detection point on the screen) are determined, the photon follows the established path as far as no other obstacle is introduced in its path afterwards.

Now we have got rid of the counterintuitive idea of 'wave function collapse'. The photon's path is established at the instant of its emission. The 'wave collapse' and interference pattern exist only at the instant of creation (emission) of the photon and its path. There is no 'collapse' of the main packet. The main packet moves in a definite path formed at the instant of emission. It is easy to visualize how the new model of the photon avoids the need for 'wave function collapse'.

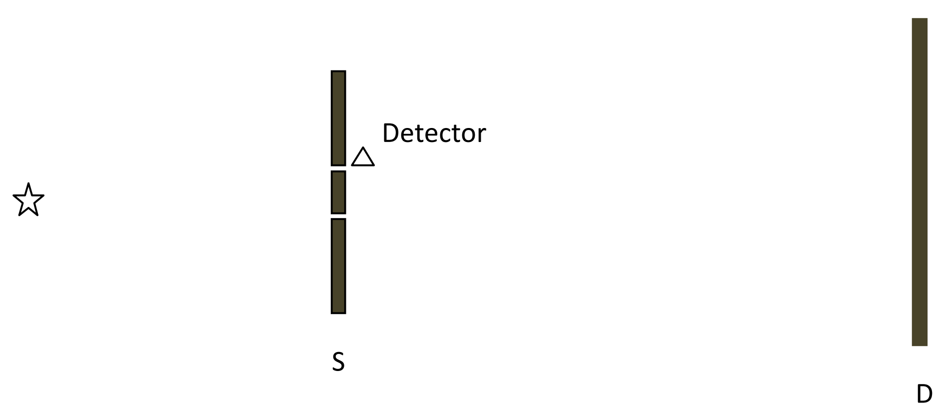
We can now understand the formation of interference patterns. The experimentally observed interference pattern is determined by, and is an image of, the brief interference pattern which formed at the instant of photon emission. By looking at the experimentally observed interference pattern, we know that the same pattern formed at the instant of photon emission.

As the photons are shot one by one, an interference pattern will gradually develop.

Effect of observation

From experiments, we know that the interference pattern disappears if a detector is placed at one of the slits to know which slit each photon went through.

It seems as if the detector affects the path of the photon.



This puzzle is resolved by the new model of the photon. *The path of the photon is determined at the instant of emission*. At the instant of emission, a wave forms between the photon source and plate S. As discussed already, the photon takes one of the infinitely many possible paths to the plate S, depending on the probability associated with each path, without violating the principles of casualty and determinism. The photon wave (field) collapses to one path at this instant. In the case of Double-Slit experiments performed so far, the experimental arrangement is such that there is high probability that the electrons land in the vicinity of the two slits. This simply means that, in ordinary language, the electrons are fired towards the region containing the two slits.

How does placing the detector at one of the slits affect the experiment?
This is a perplexing mystery. Let us see some thoughts.

Instead of saying that the detector affected the path of the photon, let us work backwards, starting from the fact that a photon is either detected by the detector or not.

An assertion has already been made that the photon path is formed at the instant of emission. But the path taken by the photon can only be confirmed by detection. The fact that the detector has 'detected' the (precursor part of) the photon confirms that the photon took the path going to the upper slit (see figure above). We know if the photon went through the upper slit or not only from the detector. Note here that by 'detection' we don't mean detection of the main energy packet, which is just at the vicinity of the emitting atom at the instant of emission. We mean detection of the precursor wave.

Although the formation of the photon path is almost an instantaneous phenomenon, we should see it as a process and as causal to explain the effect of the detector. Therefore, what happens after the double-slit plate must be determined by what happens before the plate even at that brief instant, hence also conserving the principles of casualty and determinism.

Even though we have been saying so far that the photon path extends to infinity instantaneously, we need to see the phenomena of photon path formation as a causal to explain the 'observer effect' of the detector placed at the slit. The speed with which the light path is formed should be enormous, say billions times the speed of light.

Therefore, if a photon happens to be fired towards the upper slit (and detected there), *then it must be because the wave collapsed to that path*. Does this mean that the detector 'attracted' the photon ? We say this because we cannot monitor the almost instantaneous process (phenomenon) of photon path formation. So we infer that the precursor wave collapsed to the path to the upper slit from the fact that the photon is found to be detected there.

The above idea is clarified as follows.

A photon is always emitted towards an absorber. If no absorber exists in a certain direction relative to an emitter, no photon will be emitted towards and hence detected in that direction. The photon will be emitted only towards where it is detected at the brief instant of its creation. Remember the model of the photon as extending to infinity, as discussed already. A photon is emitted by the interaction of the emitter and an observer. If there is no emitter there will be no photon to be detected by the observer AND if there is no observer/detector there will be no *photon to be emitted from the emitter. Once a photon's path is determined and once the photon is emitted, however, it exists and propagates objectively, autonomously, whether it is observed/detected/absorbed or not.*

A photon precursor wave will collapse only to a point where there is a detector. There can be 'half photon' where there is no detector, but never a full photon. If there is no detector at the slits, half (or part) of the photon passes through the upper slit and the other half through the lower part. 65% of the photon may pass through the upper slit and 35% through the lower slit. Note that this will also affect the interference pattern. In this case, there will be points of minima on the detector screen but never with complete destructive interference which requires 50% - 50% . Where there is detector, there can be only a full photon or none. A detector can detect only a full photon.

Note that we are talking about the instant of photon path formation and hence the main photon packet is just at the vicinity of the emitting atom at this instant. We are talking about an extremely weak wave preceding the main packet. Therefore, when we said 'part of the photon goes to each slit' (in the absence of detector) we were talking about this weak wave.

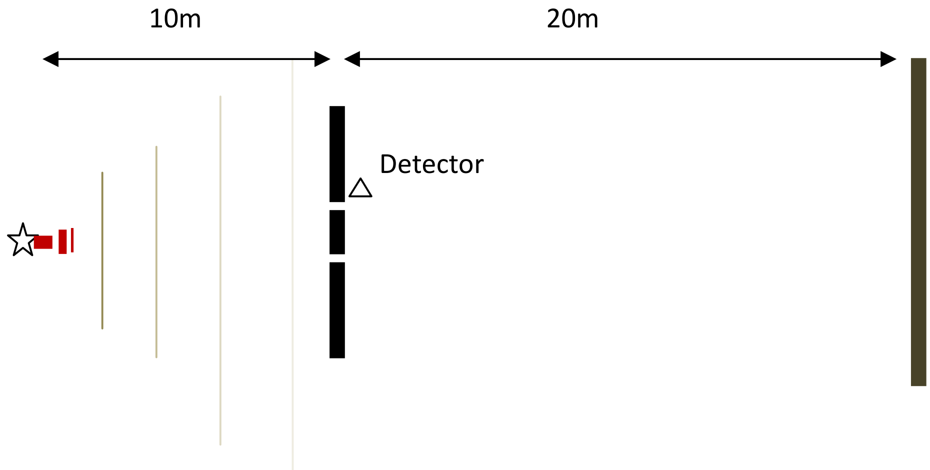
Let us review what happens with the presence of the detector at the upper slit. Since there is a detector there, a photon will either 'collapse' to that slit or be completely absent from there. Half photon cannot pass through the upper (and the lower) slit. Even though no physical detector is put at the lower slit, the effect is the same as if a detector is put there. The explanation will come in the section ahead. Suppose that the photon passes and is detected through the upper slit. Therefore, all of the precursor wave will pass through the upper slit and none through the lower slit.

Now a path of the photon from the source to the upper slit has been established. *Next* the path of the photon from the upper slit to the detector screen D will be established. This too takes place in a brief instant of time (almost instantaneously). We see that there will be no two-source interference pattern as the leading photon emerges only from the upper source. The specific point the photon will hit on the detector screen is determined by causal and deterministic probability.

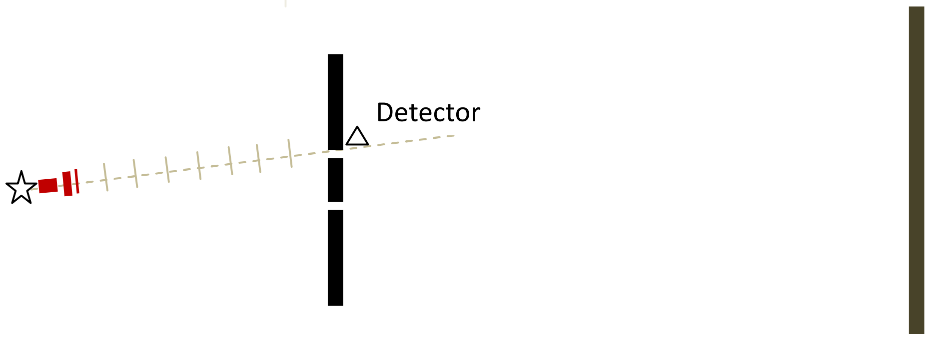
We have demonstrated that the photon path formation follows the principles of casualty and determinism. Once the two photon paths are established, the main packet follows that path until it is detected on the detector screen D.

The sequence of events and the process is shown below. The wave fronts are drawn as plane waves; actually they should be circular. Note the red and gray wave fronts. The red wave fronts represents the main photon energy packet, which contains 99.9…9% of the photon energy. The gray wave fronts represent the extremely weak wave preceding the main packet (precursor wave). Note how the gray wave fronts become more and more faint in the precursor wave, representing lesser and lesser photon energy density.

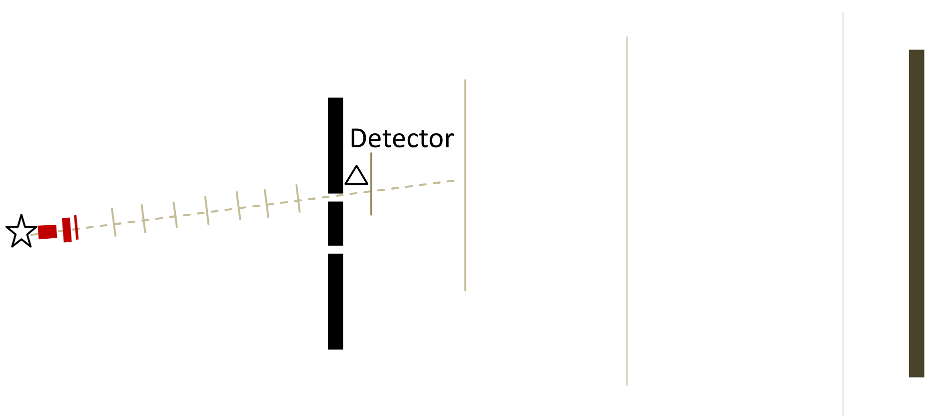
One billionths of a nanosecond (photon emission begins)



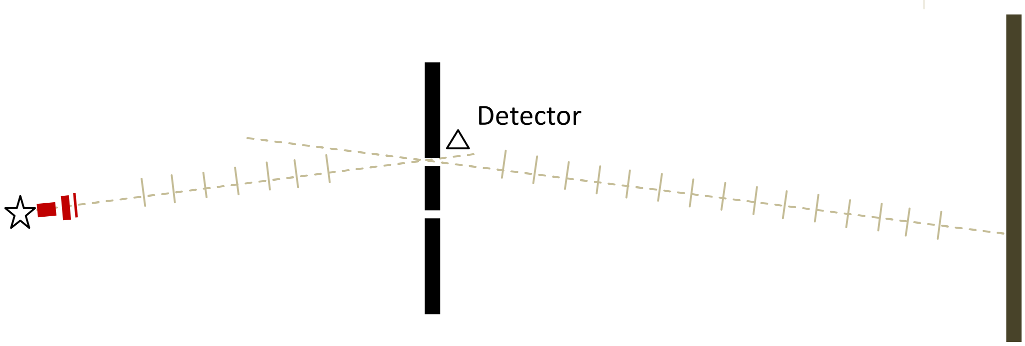
Ten billionths of a nanosecond (formation of path S, precursor wave collapses to a path)



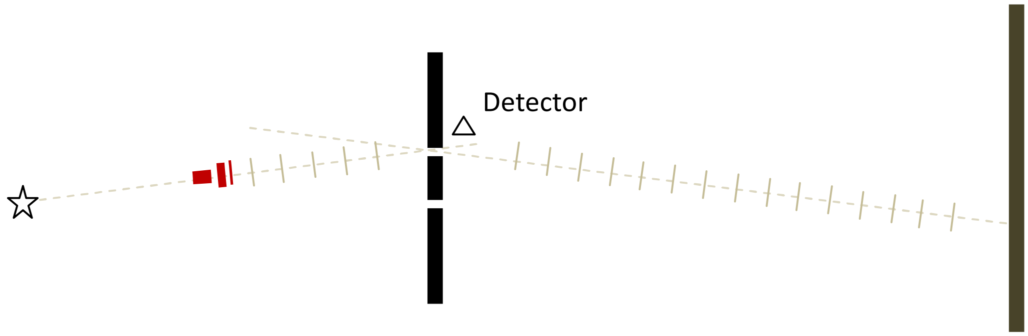
Hundred billionths of a nanosecond (precursor wave crosses slit)



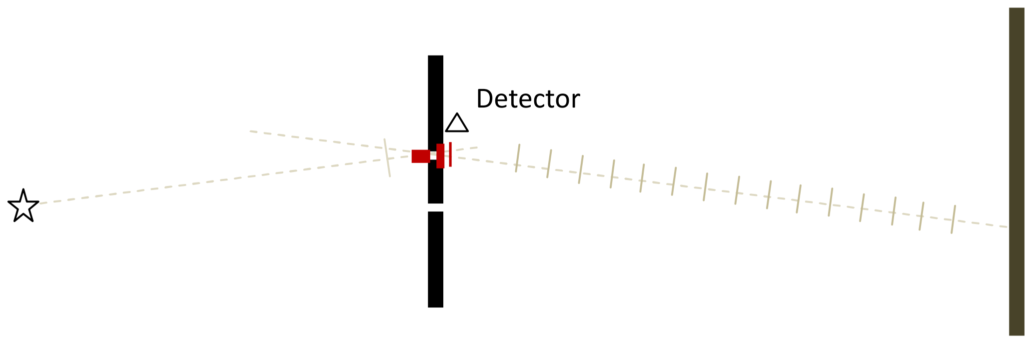
One millionths of a nanosecond (formation of path D, precursor wave collapses to a point/path)



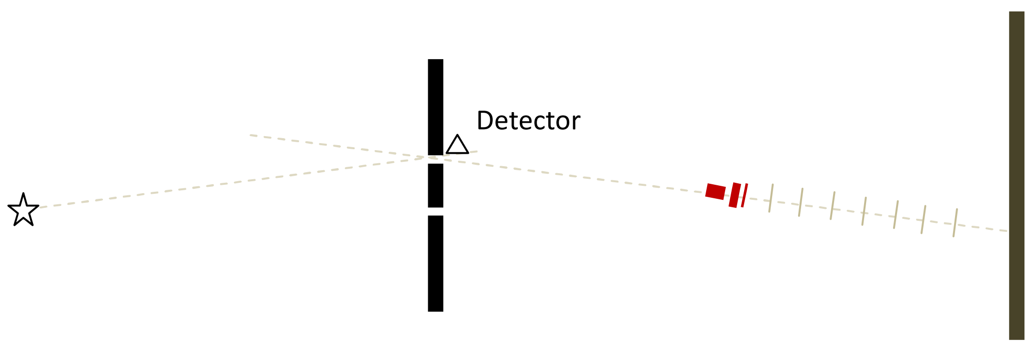
16 nanosecond
(main packet half
way)



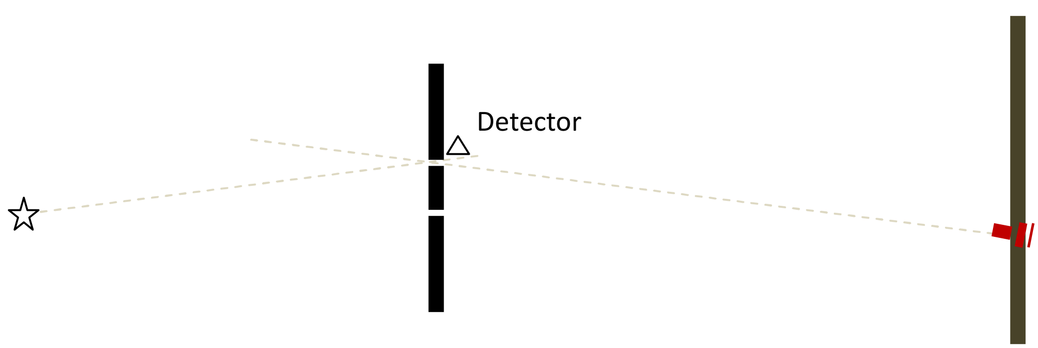
33nanosecond
(main packet
crossing slit)



66 nanosecond

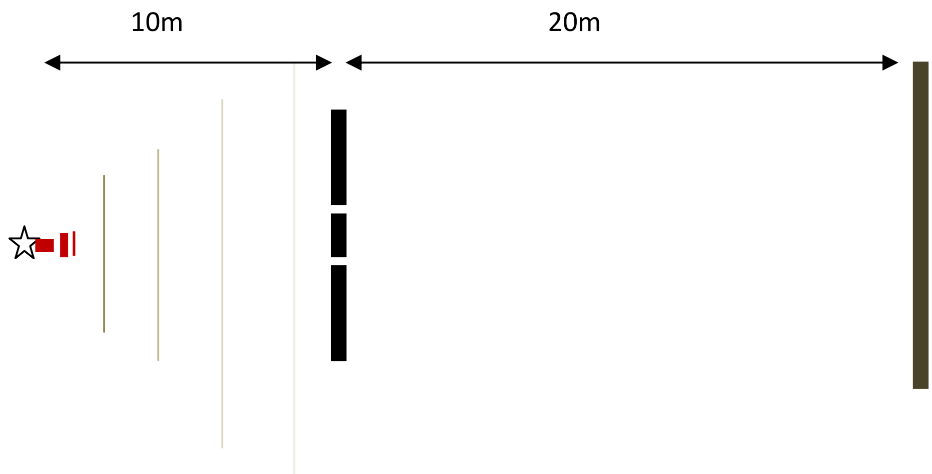


99 nanosecond
(detection on the
screen)

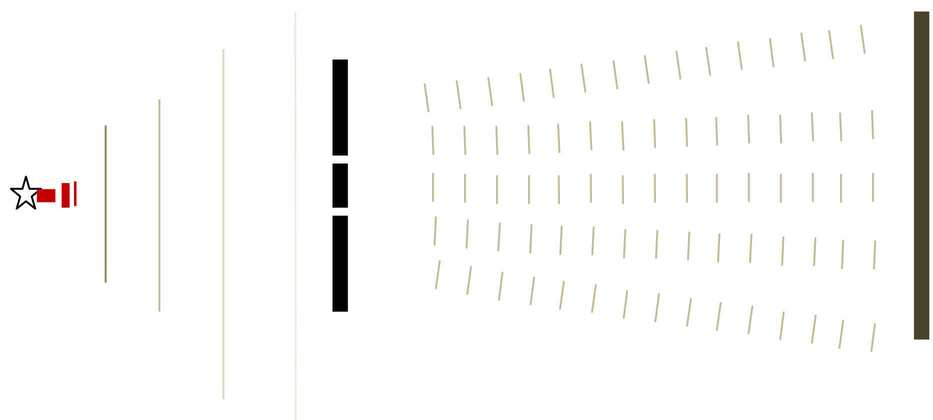


Next we see sequence of events if there is no detector at the slit.

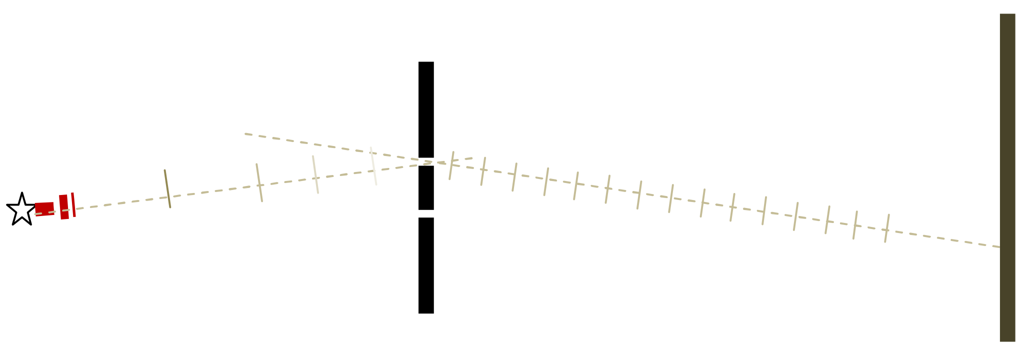
One billionths of a nanosecond (photon emission begins)



Ten billionths of a nanosecond (photon crosses slits, forms interference pattern)



Hundred billionths of a nanosecond, (photon collapses to paths S and D)



*The time intervals shown above for the formation of photon path are only meant to show that the phenomenon of photon path formation is causal (not instantaneous)

Note that the path D and path S of the photon are formed simultaneously. The collapse of the photon to the upper slit (path D) after the S plate forces the collapse of the photon to the same slit (path S) before the plate. For example, path S will not collapse to the lower slit when path D collapsed to the upper slit and vice versa. This is based on the law proposed in this paper: a photon will be emitted only if it is absorbed and will be absorbed only if it is emitted.

Once the photon path is determined, the photon starts propagation as usual and hits the detector screen after about 99 nanoseconds.

Quantum Erasure, Which-Way

The explanation given so far on double-slit experiments is mostly based on the view that emission of light is determined only by the emitter. The role of the detector was not clear. However, we see that such an approach fails when we try to understand Quantum Erasure experiments. There is no actual detector put at one of the slits in one of the Quantum Erasure experiments. Full explanation of Quantum Erasure experiments and the usual double-slit experiments requires an approach in which both the emitter and the observer/detector have equal role in emission of the photon.

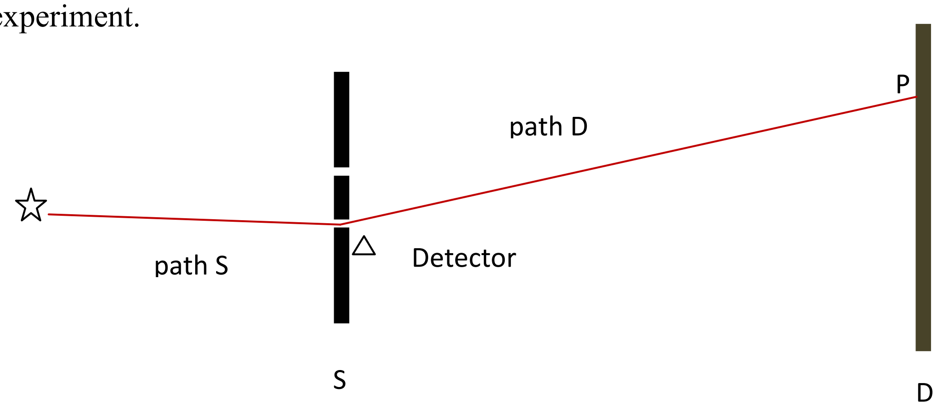
Consider a case in which the polarizer is not there (diagram below). From experiments we know that the interference pattern will disappear, showing that the photon passed through only one of the slits. The puzzle is: how does the photon source know not to direct the photon to both slits ? And how does the detector know where to detect the photon so that the photon cumulatively forms a bell-shaped pattern and not an interference pattern?

The proposed resolution of the puzzle is presented next.
The emission, propagation and absorption/detection of a photon are not separate processes; they are interlinked. A photon is emitted only to where it is detected. The emission of a photon is a result of interaction of the emitter and the detector.

The complete process consists of two coupled processes
1. Detector detects the photon at a certain point (on the detector screen).
2. Emitter emits the photon to a certain direction (the upper slit, the lower slit, or both slits)

The above two processes are coupled and determine the photon path.

Let us take this approach to explain the previous experiment, before engaging with the Quantum Erasure experiment.



We start from the detectors. The precursor part of the photon starts to be detected at an *arbitrary* point P on the screen at an instant of billionths of a nanosecond. (Remember again the new model of the photon as extending to infinity or, at this initial brief instant, extending nearly instantaneously to the detector). This detection is at an extremely/infinitely small energy level. The detection of the photon starts at the instant of emission. (Note that the main energy packet is yet in the vicinity of the emitting atom at this instant.) According to the principle that a photon will go only to where it is detected, the fact that it is detected at point P further makes the photon go to the same point. Going backwards, there are two possible paths to point P: from the upper slit or from the lower slit. In this case the path is determined by detection at two points: at point P and at the lower slit. Whether the photon takes the upper or the lower slit is based only on a casual and deterministic probability. Assume that the photon initially is detected at the lower slit. The fact that it is detected at the lower slit further makes the photon go to the lower slit , i.e. collapse to path S on the emitter side. Note again that this is according to the principle that a photon will go to where it is detected. Now the path D and path S of the photon is established, by starting from the detector.

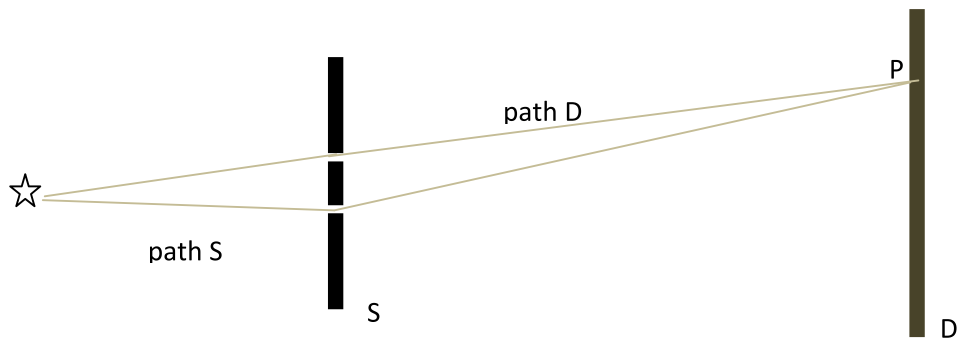
Next we start from the emitter. At the instant of emission, an extremely faint photon wave will form between the emitter and plate S. From our previous discussion, the precursor part of the photon will be directed to either the upper or the lower slit, because of the presence of the detector. Since it already collapsed to the lower slit (preceding paragraph), it will go to the lower slit, diffracts as it passes through the slit. It can collapse to any of the infinitely many possible paths. The question is: which of those paths will the photon take to the detector screen? Will it go to a point different from point P? In fact, the photon collapses to the same path to point P.

But why does the photon choose the path already established from the detector side? From the previous discussion we saw that an interference pattern will form if the precursor photon wave passes through both slits (i.e. with no detectors placed at the slits) and no interference pattern will form if the initial wave passes only through one slit. The question is: How does the precursor part of the photon know where to land on the detector screen to form the bell-shaped pattern that is compatible with the 'rear' photon which will pass only through one slit (b/c of presence of detector at the slit)? How does the emitter know to direct the photon only to the lower slit and not to both slits? And how does the detector screen know at which point to detect the photon so as to form a bell-shaped pattern and not an interference pattern? This puzzle stands out especially in the Quantum Erasure experiment to be discussed shortly. The answer to this question is one of the mysteries revealed in this paper. The two processes are closely coupled and are actually one phenomenon. Emission of the photon is a result of its detection and detection of the photon is a result of its emission. The photon is emitted from the source by the interaction of the emitter and the detector. For example, as an answer to the above question we can say that the 'initial' detection of the photon at point P is itself a result of a 'previous' interference pattern of the same photon from the emitter side. But that 'previous' interference pattern would not occur if there was no 'previous' detection before it. And so on. So which phenomena started first? Emission or detection? Emission and detection of a photon are simultaneous and in fact are a single phenomenon, not two. Therefore, the point P is not arbitrary.

Now the path S and path D of the photon has been established from the emitter side too. The emission of the photon main energy packet takes place only after its path is established.

The fact that path D is established forces the establishment of path S. If path S goes to the lower slit, path D will also go to the lower slit. For example, path D cannot go to the upper slit while path S goes to the lower slit.

Let us see the case of no detector placed at the slits.

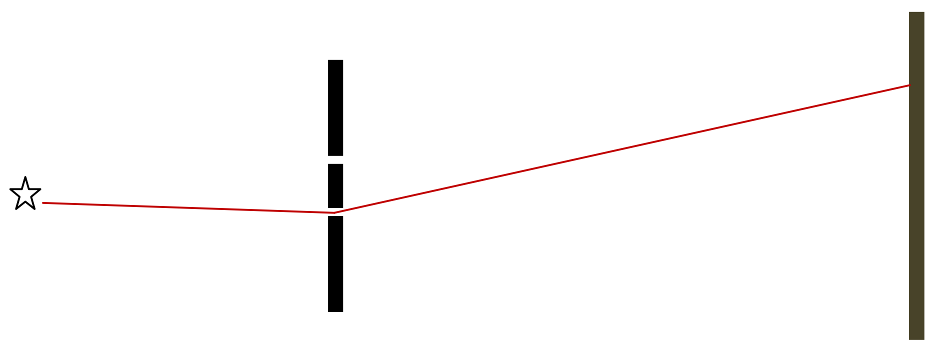


Starting from the detector side, suppose that the photon is detected at an *arbitrary* point P. This makes the photon to be further drawn to point P. We see that there are no detectors at the slits, so the precursor photon passes through both slits. The detection of the photon further makes the photon to be drawn to the slits on the emitter side.

Starting from the emitter side, a precursor wave is emitted towards both slits (previous paragraph). This forms an interference pattern in the region between plate S and screen D. As discussed previously, the photon takes one of infinitely many possible paths. Since the photon has already been detected at point P (preceding paragraph), the photon will take the path to point P. The question again is: How does the precursor photon know to form an interference pattern and not a bell-shaped pattern? How does the precursor photon know where to be detected 'initially' to form an accumulated interference pattern. One may answer: the 'initial' detection of the photon at point P itself is a result of a 'previous' interference pattern. But which started first? Emission or detection? The answer is: both occur simultaneously. This is the evolution of the photon path.

To restate the above: if we start from detection of the photon at an *arbitrary* point on the screen, how does the photon know where to land so that it will cumulatively form an interference pattern? The answer will be: the detection of the photon at point P itself is due to a 'previous' interference pattern of the same photon. If the photon was not initially emitted from the source, it would not be detected on the screen and vice versa. The point P, for example, can never be a point of complete destructive interference. Therefore point P is not arbitrary.

Which slit the main photon packet passes through is based on causal and deterministic probability, as already stated. Note that the main photon energy packet always passes through only one slit (whether a detector is placed at the slits or not), hence in agreement with particle behavior. Assume that the photon takes the lower slit on the detector side. Once the path D is established, this causes the determination of path S also: path S also goes to lower slit. The photon cannot collapse to different slits on the two sides of the plate S. When it collapses to the lower slit on the detector side, this makes its path collapse to the lower slit on the emitter side too (see figure below). An interference pattern gradually develops as the photon is fired towards the slits one by one.



Now the Quantum Erasure (Which-Way) experiment will be explained.

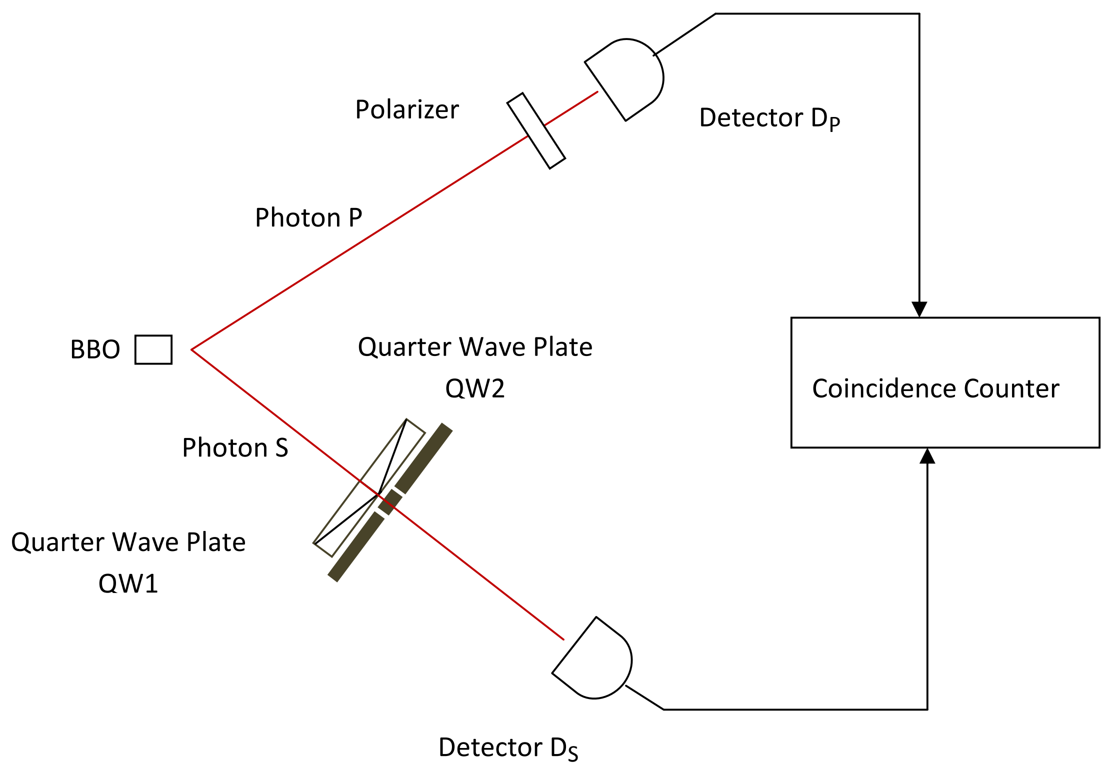
Assume first that the Polarizer is not there.

Let us start from the detectors D_P and D_S. Assume that the photon detected at D_P has X polarization. And that the photon detected at D_S has right (clock-wise) polarization. Now we go backwards. Since the polarization of photon S will be Y, we know that photon S has passed through Slit 1. From this we know that photon S took the path from BBO to slit 1.

Now we start from the BBO. The BBO will emit the photon S towards Slit 1, in agreement with the path established from the detector side (preceding paragraph). As the photon passes through Slit 1, it will undergo diffraction, but the wave will collapse to one of infinitely many possible paths. But the path already established from the detector side will be selected. Suppose that thousands of photons are emitted one by one. From experiments we know that they form a bell-shaped (Gaussian) pattern and not an interference pattern because the photon passes only through one of the slits in this case. The question is: how does each photon know where to be detected 'initially' so that a bell-shaped pattern, and not an interference pattern, (or vice versa, in case the polarizer is put in place) will form cumulatively? And how does the emitter know to direct the photon to Slit 1? The explanation of this has already been given. If we start by assuming an arbitrary point of detection for the photon, the argument is that that is itself a result of a 'previous' bell-shaped pattern from the same photon, which is again a result of previous detection at the same point and so on. The emission and detection and path formation of the photon is an evolution.

Now the path of the photon has been established. Note that these events (processes) are completed almost instantaneously, say one millionths of a nano second. At this instant, the main packet of the photon is still in the vicinity of the emitting atom.

As the pairs of twin photons are emitted one by one, a bell-shaped pattern will form.



One photon and two photon interference

The single photon and single electron Double-Slit experiments confirmed that the interference patterns observed are due to photon (and electron) self interference. The scientific community settled with the view that a photon interferes only with itself. However, interference pattern was later observed with two laser light sources also.

In this paper it is proposed that one photon interference is a quantum phenomenon, where as two photon interference is a (semi) classical phenomenon.

Let us examine Paul Dirac's statement that a photon interferes only with itself. What does this really mean? A photon is an electromagnetic energy. It acts on charged particles with its electric and magnetic fields. Therefore, just as two electric charges can both act on a single charge at the same time, two photons can also act on a single electron simultaneously. This is a classical phenomena and there is nothing strange about it. If Dirac's statement is interpreted that two photons cannot act on the same electron at the same time, then it would be wrong. It would be wrong for the same reason that it is wrong to say that two charges cannot act on a single charge at the same time, that two mechanical forces cannot act on a single body simultaneously.

Interference pattern would not occur from ordinary light sources only because they are not coherent . Interference pattern will form from two lasers with the same frequency, for the duration of coherence.

Therefore, there will be nothing strange about interference of two lasers.

However, a photon can also interfere with itself and this was strange at the time it was discovered. The interference of a photon with itself determines the path of the photon, for example in the Double-Slit experiment as discussed already. A photon's lateral dimension is limited. A photon can be visualized as a line, as a ray.

A photon, once emitted, will never 'mix' with another photon. Two photons can be at the same place at some point and keep their 'identity'. If two photons act on an atom and are unable to be absorbed, because of partial destructive interference, then both will be reflected. There will never be complete destructive interference between two photons. Complete destructive interference can occur only between two continuous classical waves.

Quantum Entanglement (EPR Paradox)

The EPR paradox is a paradox arising from the Copenhagen interpretation. According to this paper, the parameters (polarization, frequency, …) and direction/path of the two entangled photons are determined at the instant of emission.

Conclusion

A few, closely related, simple and subtle laws governing quantum phenomena have been proposed in this paper. The puzzles of quantum mechanics are: 1. what is the medium for the photon wave and for the electron wave ? 2. How can particle interference pattern be explained ? 3. How can observer effect be explained? The new model of the photon (and the electron) resolves these puzzles.

Thanks to God and His Mother, Our Lady Saint Virgin Mary.

References

1. Unlocking the Mystery of Interference Patterns in Electron and Photon Double-Slit Experiments and the Puzzle of 'Waves Without Medium' (http://vixra.org/abs/1411.0556)