Hi Rajneesh,

DISCLAIMER The selection of colors in this illustration is completely arbitrary and is not intended to indicate any correspondence to actual colors in physical reality. The colors were selected merely to highlight the addition of amplitudes in Figure 4, segment "g".

Next Phase. Aug 7, 2000

It is now desirable to introduce a **sine wave component** into ***both*** the model's ***particle*** and its ***line*** modes of operation. The following table and diagrams (Figs. 1-4) illustrate importance of sine wave phase in the paradoxical and counterintuitive effects observed experimentally when light is physically manipulated by means of full and partial reflections and which we seek to more clearly illuminate by means of computer graphics..

TWO PRINCIPLES OF PHASE:

1) Each time light is reflected (*by either a* ***full*** *or a* ***half silvered*** *mirror*) its phase is retarded **90 degrees.** The reflected wave is phase shifted **90 degrees** relative to the incident wave, so that it lags the incident wave by **90 degrees**..

2) When light is transmitted through a ***half silvered*** mirror its phase remains unaffected.

THE POSSIBLE PARTICLE DETECTION PROBABILITIES AT THE FIXED DETECTORS "X" & "Y"

Wave-Function or Particle Trajectory Blocked	Detector Lit Up	Probability of Individual Particle Detection
Both Yellow and Blue **c and b or** **c and d or** **e and b or** **e and d** **Figure 1**	**no detector** (---------)	**0 at dectector X &** **0 at detector Y**
Segments "c" and/or "e" **"Yellow"** **Figure 2**	**both detectors** ("X" and "Y")	**1/4 at detector "X" &** **1/4 at detector "Y"**
Segments "b" and/or "d" **"Blue"** **Figure 3**	**both detectors** ("X" and "Y")	**1/4 at detector "X" &** **1/4 at detector "Y"**
none **Figure 4**	**detector "Y"** ("Y" or nothing)	**1/2 nothing &** **1/2 at detector "Y"**

A) If (*as in Fig. 1*) all possible paths to a detector *are blocked*, then neither detector **"X"** nor detector **"Y"** ever light up.

B) If (*as in Fig. 2 & 3*) ***either one, but only one, of*** the possible ***yellow*** or ***blue*** trajectories to the ***2nd half silvered*** mirror *is blocked*, then both of the detectors **(*"X" and "Y"*)** light up individually half of the time (*on the average*) and never at the same time.

C) If (*as in Fig. 4*), *none* of the possible ***yellow*** or ***blue*** trajectories *is blocked*, then only detector **"Y"** lights up and even it lights up only **1/2** of the time (*on average*).

1) because of "***destructive interference"*** between **'Bf'** and **'Yf'** which are **180 degrees** out of phase, detector **"X"** no longer lights up and

2) the ***1/4*** amplitude **'Bf'** and the ***1/4*** amplitude **'Yf'** interact by adding amplitudes through ***"constructive interference"*** to become the ***1/2*** amplitide **'Gf'** at ***segment "f"***. **'Gf'** is observed when it strikes detector **"Y"**

THE PARADOX (*from the view point of classical physics*):

When (*as in Fig. 1 following*) *all* of the light is intercepted by ***movable*** photodetectors (**m1** and **m2**) then the fixed photodetectors (**X & Y**) remain unlit and an individual photon is observed only by one, or the other, but never both, of the intercepting ***movable*** photodetectors

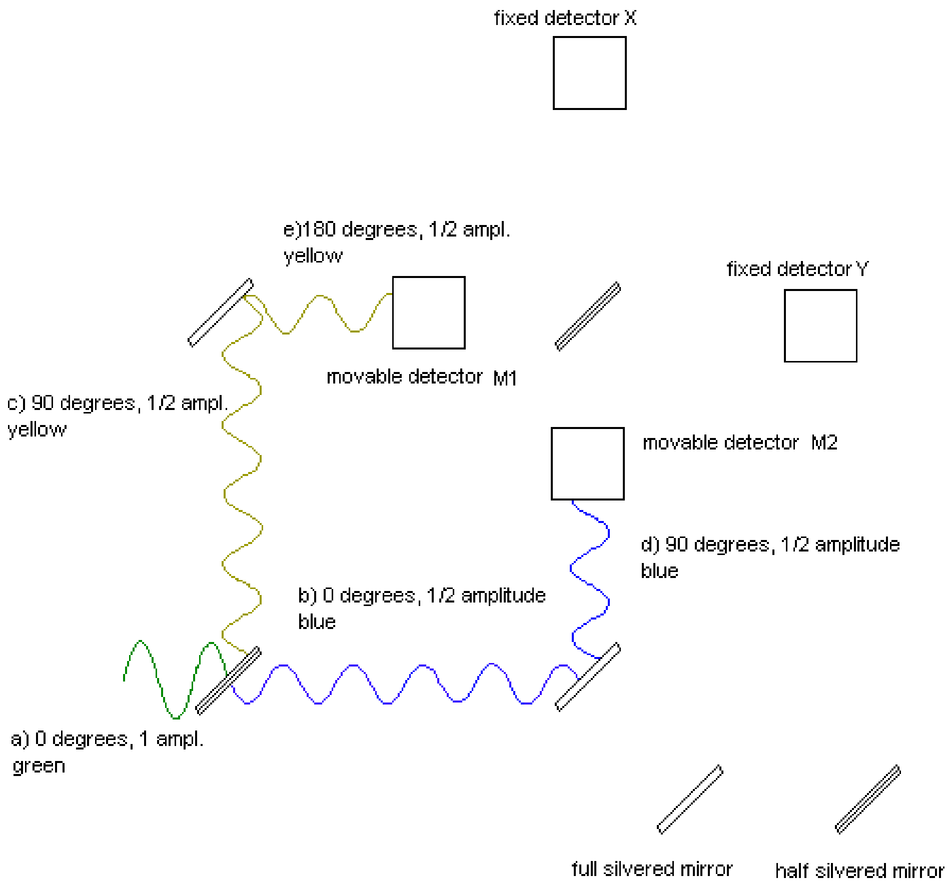

Figure 1 Both paths (yellow & blue) are intercepted by movable photo-detectors

Even though the wave packet goes simultaneously to both movable detectors (**m1** and **m2**) the wave-packet of an individual particle is observed registering as a particle at only one ***movable*** photodetector or another. This fact illustrates the idea that the wave function is really just a potentiality, or at least its *interpretation*, is in terms of a potentiality (*or* ***potentia***) for an event to occur.

> Because even though the wave packet (*if you follow the* ***Schrodinger equation***) splits and reaches both ***movable*** photodetectors, traversing both possible photon paths simultaneously, only one or the other of the ***movable*** photodetectors will fire. You know when you place your ***movable*** photodetectors to intercept both the ***blue*** and ***yellow*** segments, only one photodetector or the other will fire per individual photon traversing the apparatus.

When *half* of the light is intercepted by a ***movable*** photodetector then both fixed detectors (**X & Y**) light up but each separately and each only 1/4 of the time(*on average*). [See Figures 2 & 3 below]

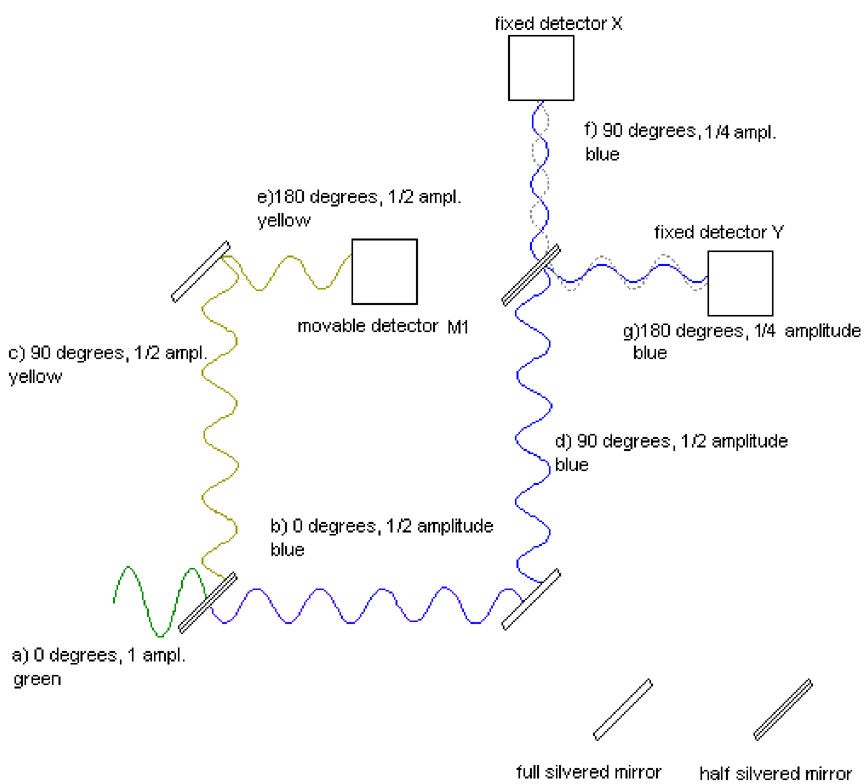

Figure 2 The yellow path is intercepted by a movable photo-detector.

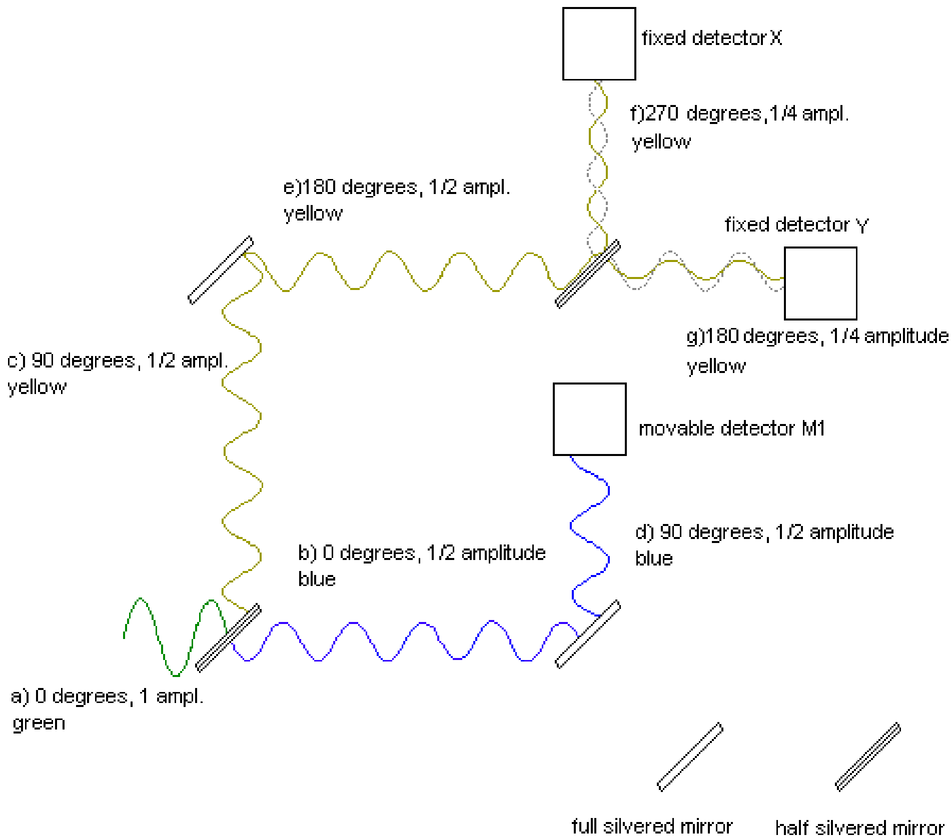

Figure 3 The blue path is intercepted by a movable photo-detector.

When *none* of the light is intercepted by movable photodetectors only one fixed detector (**Y**) lights up and that only 1/2 of the time (*on average*). [Figure 4 next page]

Up until this stage everything has looked classical at least in the sense that the particle is either going one way or the other (*i.e. taking the blue or the yellow path*).

Now, in both segments ***"f"*** and ***"g"***- is observed, not the sum of the two amplitudes from the ***yellow*** and ***blue*** paths (*as you might expect from common sense*) instead, the ***green*** sum is observed only in ***"g"*** while in ***"f"*** you get this strange cancellation.

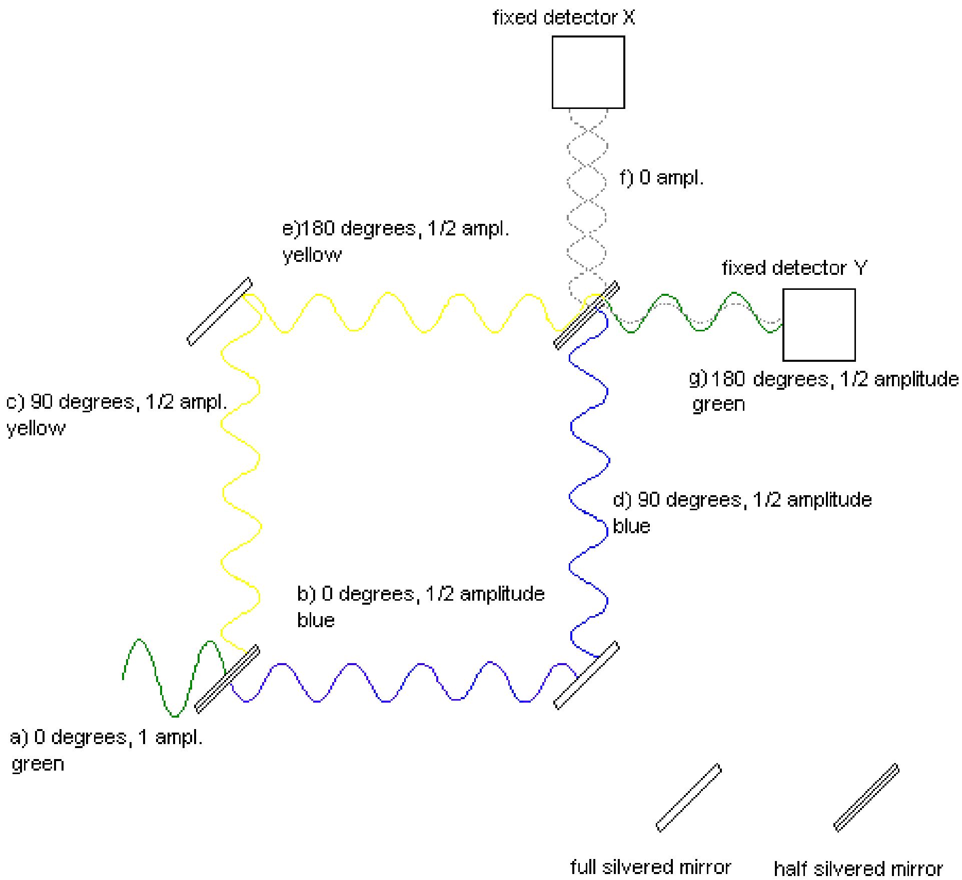

Figure 4 Neither the blue or yellow paths are intercepted and a mysterious cancellation occurs in *segment "f."*

THE PARADOX (*from the view point of the Copenhagen Interpretation*):

This strange cancellation occurs even with each individual photon traversing the apparatus one at a time.

Apparently the photon's wave-function is interfering with itself independently of any measurements or observations. The Standard **Copenhagen Interpretation** of **Quantum Mechanics** states that the photon's wave-function is only a representation of our knowledge about the photon. That it is a description of anything in the physical world is denied.

The **Copenhagen Interpretation** fails to account for how such a mere ***"representation of our knowledge"*** can interfere with itself, outside of, and independently of, our conscious minds.

However the **von Neumann / W igner** interpretation does provide such an account. It suggests that we take the mathematical foundations of **Quantum Theory** seriously. It suggests that the photon's wave-function actually models and corresponds to something that exists independently of our minds, in reality itself.

The **von Neumann / Wigner** interpretation seems a much more natural explanation of the wave-function's interference effects in this experiment.

ILLUSTRATION OF THE RELATIONSHIP OF PHASE
TO THE CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE IN SEGMENTS "F" AND "G"

Segment a:

This segment begins as a sine wave emanating out of the cone and ends with it striking the first half silvered mirror. This initial full amplitude wave-function (*colored* ***green***) is **0 degrees** out of phase with itself (*of course*) and has a probability amplitude of **1** (*meaning that it always observed traversing* ***segment a*** *in* ***any*** *chosen experiment*). Upon striking the first ***half-silvered*** *mirror*, the wave function of an individual photon splits into the superimposed possibilities of two different photon trajectories to the ***2nd half-silvered*** mirror. These two superimposed path possibilities are represented in the illustration as the ***blue segments "b-d"*** and the ***yellow segments "c-e"***.

Segment "b"

Segment "b" (*colored* ***blue***) is transmitted through the ***half-silvered*** mirror as a sine wave **0 degrees** out of phase with ***segment "a"***, and carries one half of the amplitude carried by the sine wave in ***segment "a"*** (*the* ***not-segment "c"*** *half*). It finally strikes a ***full silvered*** mirror (*lower right*).

Segment "d"

Segment "d" is reflected by the ***full silvered*** mirror (*lower right*) as a sine wave. The **wave-function** is thus retarded so that it is **90 degrees** out of phase with the phase of ***segment "a"*** and continues to carry an amplitude of ***1/2***.

Segment "c"

Segment "c" (*colored* ***yellow***) is reflected by the ***half-silvered*** mirror as a sine wave and thus its phase is retarded **90 degrees** relative to the phase of ***segment "a"*** ***Segment "c"*** carries the other half of ***segment "a"'s*** amplitude (*the* ***not-segment "b"*** *half*). It finally strikes the **full silvered** mirror (*upper left*).

Segment "e"

The **full silvered** mirror reflects ***segment "c"*** into ***segment "e"*** and in the process retards its phase **90 degrees** further.. It is now **180 degrees** out of phase with the phase of ***segment a*** but it still has an amplitude of ***1/2***.

When they reach the ***2nd half-silvered*** mirror, both wave-packets of the two photon trajectories (***segments b-d*** and ***segments c-e***) again each split into two more wave-packets or possible photon trajectories. This creates a set of four superimposed wave-packets waiting for an observation (*measurement*) to collapse the set of possible states into one manifest actuality.

The ***blue*** and ***yellow*** wave functions each split so that they both occupy ***segments f*** and ***g*** simultaneously. Simultaneously with each other and with themselves.

An individual photon can only be observed traversing the spaces of either ***segments "b-d"*** or ***segments*** *"c-e"* never both. The wave-function representing the possibility of finding this individual photon in either space *is* however at both spaces simultaneously until it is collapsed by a measurement into just one having traversed just one space..

This local/non-local relationship between the observable characteristics of an individual photon and its wave-function is also observed in the two possible trajectories represented by ***segment "f"*** and ***segment "g"***.

Destructive and Constructive Interference in Segments "f" and "g"

An individual photon traversing ***segment d*** can be observed to be transmitted through the ***2nd half-silvered*** mirror to detector **X (**at the end of ***segment "f"***) **['Bf ']** or it can be observed to be reflected off of the ***2nd half-silvered*** mirror to detector **Y** at the end of ***segment "g"* ['Bg']**.

An individual photon traversing ***segment e*** can be observed to be reflected off of the ***2nd half-silvered*** mirror towards detector **X** (at the end of ***segment "f")* ['Yf ']** or it can be observed to be transmitted through the ***2nd half-silvered*** mirror to detector **Y** (at the end of ***segment "g"***) **['Yg']**.

When (*as in Fig. 4*) none of the paths (*trajectories*) are blocked, the 4 possible states (**Bf, Bg, Yf, Yg**) of the wave function of even just one individual photon, manifest as ***"destructive interference"*** in ***segment "f"*** and as ***"constructive interference"*** in ***segment "g"***.

'Bf ' + 'Yf' = nothing

Half of the time on average, **when none of the trajectories are blocked,** the **1/2 amplitude 'Bd'** is ***"transmitted"*** and the 1/2 amplitude **'Ye'** is ***"reflected"*** along segment "f" as the **1/4 amplitude 'Bf'** and the **1/4 amplitude 'Yf.'** **'Bf'** is **90** and **'Yf' 270 degrees** out of phase with the phase of ***segment 'a'*** they are thus ***180 degrees*** out phase with each other. Consequantly **'Bf'** and **'Yf'** manifest complete ***"destructive interference"*** with each other, becoming when combined together, **nothing,** the result is an amplitude of zero. (*they cancel each other out*). You do not see anything.

'Bg' + 'Yg' = 'Gg'

The other half of the time, when none of the trajectories are blocked, 'Bd' and **'Ye'** are ***"reflected"***, and ***"transmitted,"*** along segment "g" to become the **1/4 amplitude 'Bg'** and the **1/4 amplitude 'Yg'** respectively, Because **'Bg'** and **'Yg'** are both **180 degreees** out of phase with the phase of ***segment 'a'*** they are **0 degrees** out of phase with each other. Consequantly **'Bg'** and **'Yg'** manifest complete ***"constructive interference"*** with each other, doubling their amplitude when combined to form the ***1/2*** **amplitide 'Gg'.**

When (*as in Fig. 2 & 3*) one and only one of the paths (*trajectories*) are blocked, there is no interference (*whether constructive or destructive*) between the 4 possible states (**Bf, Bg, Yf, Yg**) of the wave function of an individual photon,

'Bf' + nothing ='Bf'
'Bg' + nothing ='Bg'

When (*as in Fig. 2*) the yellow paths are blocked [**'Yc'** and/or **'Ye'**] **so that only photons traversing the blue path** [**'Bd'** **] get through** to the ***2nd half-silvered*** mirror, then each detector (**X** for **'Bf'** and **Y**for **'Bg'**) lights up one half of the time, but never at the same time for any individual photon.

'Yf' + **nothing** =**'Yf'**
'Yg' + **nothing** =**'Yg'**

When (*as in Fig. 3*) the blue paths are blocked [**'Bb'** and/or **'Bd'**] **so that only photons traversing the yellow path** [**'Ye'** **] get through** to the ***2nd half-silvered*** mirror, then each detector (**X** and **Y**) lights up one half of the time, but never at the same time for any individual photon.

Unlike the individual photon which can only be observed to be reflected *or* transmitted, the wave-function of an individual photon traversing ***segment "d"*** is simultaneously both transmitted through the ***2nd half-silvered*** mirror to detector **"X"** (at the end of ***segment "f"***) **[Bf]** and reflected off of the ***2nd half-silvered*** mirror to detector **"Y"** **(**at the end of ***segment "g"***) **[Bg]**.

Unlike the individual photon which can only be observed to be reflected *or* transmitted, the wave-function of an individual photon traversing ***segment "e"*** is both reflected off of the ***2nd half-silvered*** mirror to detector **"X"** (at the end of ***segment "f"***) **[Yf]** and simultaneously transmitted through the ***2nd half-silvered*** mirror to detector **"Y"**(at the end of ***segment "g"***) **[Yg]**.

There is a lot here so let us know if you have any questions.

Thanks,

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