Are We Using Bell's Inequality Wrongly in Polarization of Light Experiments?

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Abstract

Bell's inequality is a widely used theorem to prove that quantum mechanics violates principle of locality. Polarization experiments are used in this regard. This article is an examination to see whether there is any loop hole in our usage of polarization experiments to prove that quantum particles violate Bell's inequality. In this article, the probability distribution of unpolarised light is examined. On doing so, it is found that the realignment of polarization axis of photon on passing through a polarizer may be the cause of more than expected probabilities

Keywords: photon, polarisation, Bell's inequality, unpolarised light.

One of the commonly described experiments to explain realism in quantum mechanics is the polarization of light experiment. The principle of locality is rejected using Bell's theorem[1]. In polarization of light experiments, the light from a source is passed through polarizers and probability distribution is analysed. It is shown to violate the Bell's inequality theorem[2]. This gives rise to questions of faster than light communication and questions regarding the validity of theory of special relativity.

In this article, We look into the polarization of unpolarised light. This article examines the probability distribution of unpolarised light and make an attempt to explain the missing part in the experiments.

Let us imagine the experiment. In the first stage, we use an unpolarized light to pass through a vertical filter(A). Let P(a) be the probability that photons pass through filter A and P(a-) be the probability that photons fail to pass through filter A. Fifty percent photons will pass through and fifty percent fail to pass. Therefore,P(a)=P(a-)=50%

When we use a horizontal filter (B) for the vertically polarized light, no photons will pass through. Let P(b) be the probability that photons pass through filter B and P(b-) be the probability that photons fail to pass through filter B. Then P(b,a)=0. The quantum mechanics predict that the probability is given by $\text{Cos}^2\theta$. θ is the angle between electric field of photon and the axis of polarizer.

In second stage, we use a vertical filter(A) for the unpolarized light. The probability of passing is fifty percent through the filter. After that we place the 45 degree filter(C) in between vertical and horizontal filter. Let P(c) be the probability that photons pass through filter C and P(c-) be the probability that photons fail to pass through filter C. Now we will observe that 50 percent of the photons pass through 45 degree filter and 50 percent of the passed photons will pass through the horizontal filter.

In third stage, we use filters at 22.5 degrees(D) and 45 degrees. Let P(d) be the probability that photons pass through filter D and P(d-) be the probability that photons fail to pass through filter D. As the light pass through 22.5 degrees, the amount of photons pass through is 85 percent and fail to pass is 15 percent. If we place a filter at 45 degrees behind 22.5 degree filter, we observe that again 15 percent fail to pass. If we would have directly placed 45 degree filter behind the vertical filter, the probability of fail to pass is 50 degrees. Therefore, P(c-/a) > P(d-/a)+ P(c-/d). This violates Bell's theorem.

P(c-/a) should have been 30%.

Let us see whether there is any loop hole in the experiment. When we consider unpolarised light, it means it has random polarization. So according to the above experiments a photon aligned at 45 degrees has a 50 percent chance to pass through the vertical filter. If it has retained its polarization alignment after passing through the vertical filter, it has a 50 percent chance that it pass through horizontal filter as it will be at 45 degrees to horizontal filter also. We know that the probability is given by $\text{Cos}^2\theta$. But it is blocked off by the horizontal filter. This means that even though it passes through the vertical filter, it wont maintain its original polarization axis. It gets vertically polarized. So the vertically polarized light does not means that the polarization of that photons were vertical before using filter.

The argument which may come is that the unpolarised light contains an equal distribution of vertical and horizontally polarised photons. But the most feasible explanation is that unpolarised light has uniformly distributed polarization in 360 degrees. Let n number of photons are in each axis. The average probability with which a photon pass through the vertical filter is given by the formula, $P(x)= n\sum \text{Cos}^2\theta / 360\, n$.

$\sum \text{Cos}^2\theta$ gives the sum of probabilities in each axis. Its value is 180. Therefore, P(x)= 0.5 or 50%. This is why we get a half intensity light when we use polarizer on unpolarised light. This tells us that we should consider the realignment of photons to the axis of polarizer when we analyse the probability. This realignment is probably the hidden variable. This variable causes the observed probability values higher than the expected values.

CONCLUSION

This article examines whether there are any loop holes in polarization experiments. Here we considered the unpolarised light from the source. We understood that there is a uniform distribution of photons in each axis. This meant that the photon undergo realignment of axis of polarisation on going through the polariser. This may be the reason why we get higher probabilities than expected in polarisation experiments.

REFERENCES

1. J. S. Bell, Physics I, 195-200 (1964) (reprinted in J. S. Bell, Speakable and Unspeakable in Quantum Mechanics, 2nd ed., Cambridge University Press, 2004)

2. Aspect, Alain & Grangier, Philippe & Roger, Gérard. (1982). Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: A New Violation of Bell's Inequalities. Phys. Rev. Lett.. 49. 91-94. 10.1103/PhysRevLett.49.91.

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