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VIRGIN PHOTONS DO NOT EXIST (*)

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Scientific models for microscopic objects (not directly observable) should satisfy three basic conditions:

i) Be logical and mathematically consistent,

ii) Be constructed from certain experimental "evidence", which implies that actual measurements have been done to the properties of some of the involved objects,

iii) Explain the corresponding macroscopic phenomena, and predict new macroscopic effects.

None of these conditions is trivial, as it is not possible to construct a structural model without resorting to various assumptions, some of them quite 'obvious', some accepted naively- or recklessly. On the other hand, the result of any measurement must inevitably be interpreted and that interpretation depends partly on the model that we want to justify. This seems to be the case of photon entanglement, a phenomenon that is explained and justified under the assumption that the photons acquire their polarization just after they have passed through a polarizer. This article aims to show that the existence of photons without polarization (virgin photons) apart from being inconsistent, contradicts a number of experimental facts.

Keywords: Scientific models, measurement, polarization, entanglement.

1 Introduction

By observing the manifestations of a physical object or a set of objects, scientists build a model of such objects and their interactions, so that the model can adequately represent such objects and their corresponding interactions.

All objects and all interactions?
It is necessary to emphasize that any model is limited to only represent the most significant objects (for example, to describe the interaction between two planets one usually ignores the presence of the remaining planets, and any asteroids) and also their more significant interactions (for example, when using an electron gun one often ignores the interactions between the involved electrons)

What are the objects and interactions that are significant?
This is a problem for which the solution heavily depends on the views and interests of the scientists working with the model under consideration.

Are the measurements made by scientists not objective?
One of the requirements for a measurement to qualify as scientific is replicability. For example, measurements of paranormal phenomena do not meet this requirement, hence its alleged results are not considered scientific results. In this regard, science has found that a single measurement of some phenomenon can only be considered as a precarious reference, while not confirmed or ruled out by other "independent" measures. This leads us to distinguish between what we call singular measurement (done once) and a measurement process. To get the "objective value" of the measurement of some property of a system, we consider two types of measurement processes which are (ergodically) equivalent:

i) Repetition, N times, of the same singular measurement, each time in 'identical' conditions , or

ii) The realization of a singular measurement on N "identical" sub-systems that do not interact.

The results of the corresponding singular measurements are probabilistic in nature, but are not arbitrary. [Ignorance of the features that have probabilistic outcomes of a measurement process helped to clarify some fraud committed by scientists]. Of course, the measurements are made under certain boundary conditions and eventually other special conditions, the same which should be specified to allow replicability . The probabilistic nature of the measurements (i.e. measurement process), that always has been accepted by experimentalists, is one of the most striking differences between the classical (theoretical) model and the quantum model of Physics. [In the case of microscopic interactions between objects should be kept in mind that the measurements must be interpreted according to the theoretical model that has been adopted. This carries the danger of vicious circles]

First the physician T. Young (1773-1829), in order to explain the experimental phenomenon of double refraction of light passing through a rhombohedron of Iceland spar (calcite, $CaCO_3$), then the mathematician A. Fresnel (1788-1827), established the transversal character of light waves. Then Maxwell (1831-1879) established that light was an electromagnetic waveform, and in 1905 Einstein (to explain the photoelectric effect) proposed a model in which light is composed of microscopic "particles" with well-defined energy, the same which later be-

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came known as photons. It must be accepted that photons are not usual particles, but special particles that, among other properties, are diffracted when they pass close to the edge of a surface (which apparently does not happen with "normal" particles). An experiment to verify that the particle model does not contradict the photon wave character in its most characteristic manifestation, was conducted by G.I Taylor in 1909 who, with a very weak light bulb, lit up a needle for 2 000 hours (≈ 3 months) which allowed the photons arrive virtually isolated. The image formed on a screen coincided with the diffraction image produced, in a very short time interval by an intense light spot.

2 Polarizers

For electromagnetic waves, particularly light in the visible range, one knows two kinds of light: "natural light", nℓ, and polarized light, pℓ.

nℓ is the light emitted by the sun or any incandescent material, while pℓ is the light that has certain transverse characteristics, which become evident when it is directed at and passes through certain objects called polarizers, which can be of different kinds: linear polarizer, LP, right-handed circular polarizer, RHCP, left-handed circular polarizer, LHCP, birefringent crystals, including a rhombohedral calcite prism, *RoCa*.

The LP, RHCP, LHCP, have the virtue of letting pass half the natural light that strikes them, and absorb the other half. Additionally, the light that has passed a polarizer acquires certain properties, characteristic of such polarizer, and is called polarized light: Lℓ, RHCℓ, LHCℓ, respectively.

A linear polarizer has a characteristic orientation, so sometimes it is convenient write LP (α) to indicate such orientation. A *RoCa* has the virtue of splitting the incident beam into two beams orthogonally polarized, and has what is known as Principal Plane [parallel to both the incident ray and the so called optical axis], characterized by an angle ψ.

Moreover, the light has energy, the transport of which is measured as intensity, J (energy per unit time). By measuring the intensity of light directed (perpendicularlly) to a polarizer, and the intensity of light that gets through the polarizer, one can know what fraction of incident light is absorbed by the polarizer, and what fraction passes through said polarizer, acquiring the polarization induced by such a polarizer, without changing its characteristic frequencies. On the other hand the fraction of reflected light is small and often ignored, which can be significant if the beam is extremely weak.

3 Experiments with polarizers.

Experimentally we know the following results:

- **Experiment 1**

If natural light, of intensity J(nℓ), is incident on a XP polarizer, (XP= LP, RHCP or LHCP), then the intensity of the polarized light that emerges from the polarizer is half the incident intensity:

$$J(Xp\ell) = \frac{1}{2}J(n\ell)$$

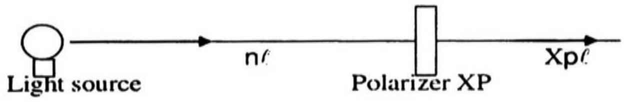

Figure 1.

- **Experiment 2**

If the light emerging from a polarizer XP, with intensity J($Xp\ell$), strikes a second polarizer X′P, "identical", to XP, then the whole incident beam passes through the second polarizer, i.e.

$$J(X'p\ell) = J(Xp\ell),$$

where XP = LP, RHCP or LHCP.

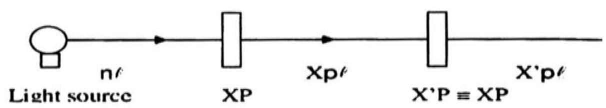

Figure 2.

- Experiment 3

Malus Law: If the light emerging from a linear polarizer LP(α) with intensity J(pℓ(α)) is incident on a second polarized LP(β), then the intensity J(pℓ(β)) of the light emerging from the second polarizer meets :

$$J(p\ell(\beta)) = J(p\ell(\alpha))\cos^2(\alpha - \beta)$$

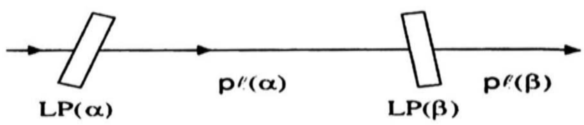

Figure 3.

- Experiment 4

If the light emerging from a linear polarizer LP is incident on a circular polarizer, CP, right-handed or left-handed, then the intensity of light emerging from the second polarizer is reduced by half,

$$J(Cp\ell) = \frac{1}{2}J(Lp\ell)$$

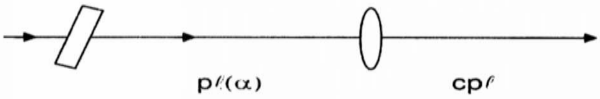

Figure 4.

- Experiment 5

If the light emerging from a circular polarizer,CP, right-handed or left-handed, hits a linear polarizer, LP, then the intensity emerging from the second polarizer is halved,

$$J(Lp\ell) = \frac{1}{2}J(Cp\ell)$$

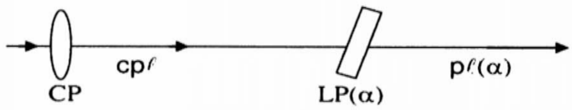

Figure 5.

- Experiment 6

If the light emerging from a circular polarizer, right-handed or left-handed, hits a left-handed or right-handed circular polarizer, respectively, then the second polarizer absorbs all light that strikes it.

$$J(Lhcp\ell) = 0$$

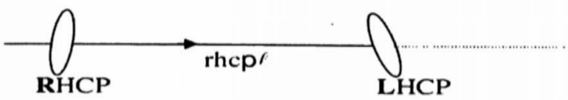

Figure 6.

- Experiment 7

If a ray of natural light falls on a rhombohedral calcite prism, then from the other end of the prism emerge two beams of linearly polarized light, with orthogonal polarizations, and each one with intensity equal to half of the incident intensity.

$$J(p\ell(\alpha)) = J(p\ell(\alpha + \frac{\pi}{2}))$$

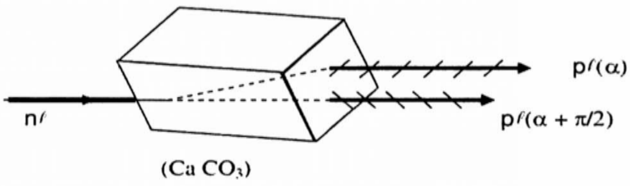

Figure 7.

- Experiment 8

If the polarized light emerging from a circular polarizer, CP, right-handed or left-handed, hits a rhombohedral calcite prism then from the other end of the prism emerge two linearly polarized beams with orthogonal polarizations, each with intensity equal to half the incident intensity.

$$J(p\ell(\alpha)) = J(p\ell(\alpha + \frac{\pi}{2}))$$

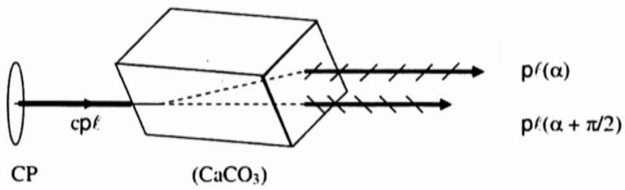

Figure 8.

- Experiment 9

If the light emerging from a linear polarizer, LP, falls on a rhombohedral calcite prism then from the other end emerge two linearly polarized beams with orthogonal polarizations, and the sum of the intensities of the emerging beams is equal to the incident intensity.

$$J(p\ell(\beta)) + J(p\ell(\beta + \frac{\pi}{2})) = J(p\ell LP)$$

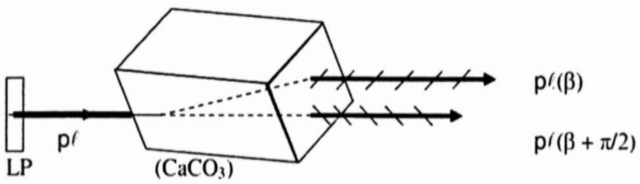

Figure 9.

- Experiment 10

If a linearly polarized beam, $p\ell(\alpha)$, is incident on a rhombohedral prism whose main plane is characterized by the angle y, then the two emerging rays will have the intensities J_1 and J_2 such that

$$J_1 = J(p\ell(\alpha)) \times \sin^2(\psi - \alpha)$$

$$J_2 = J(p\ell(\alpha)) \times \cos^2(\psi - \alpha)$$

[Note that (9) is a special case of case (10), and that for $\alpha = 45$ the two emerging rays have the same intensity, equal to half the incident intensity.]

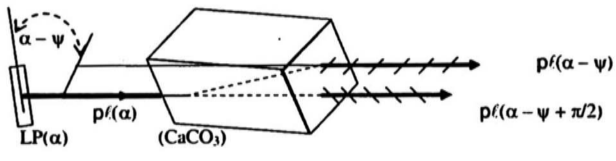

Figure 10.

We know that there exists "natural"polarized light, for example, by scattering in the atmosphere, by reflecting sunlight on the sea surface and other surfaces, by incidence of sunlight into pieces of natural crystals. Moreover, since the late nineteenth century it is known the so called Zeeman effect, whereby the light emitted by atoms placed in a magnetic field changes its polarization state. In addition, certain animals, as bees, are sensitive to polarized light and use that information for guidance, it is also believed that this is a resource of some migratory birds. Additional arguments are the rules of selection in atoms (where the spins of the photons should complement the angular momentum of the considered system) and the generation of laser light (stimulated photon decay)

If, as proposed by Einstein, light is made by special particles, called photons, all what was mentioned in the macroscopic experiments (section 3) can be explained under the assumption that photons have polarization states that can change when they interact with some objects. From Experiment 2 can be inferred that each of the photons of the light beam, once they have passed through a polarizer XP, they can go through a similar and equally oriented polarizer, without being absorbed. That is to say that experimentally a photon possesses certain polarization (eventually the polarization induced by a given polarizer). Moreover, bearing in mind Experiment 3 we can assume the existence of a quantum Malus Law, under which the photons pass through the second linear polarizer with probability $\cos^2(\beta - \alpha)$. This assumption also allows us to consider that natural light photons have randomly distributed polarization directions, which, taking into account the large number of photons involved, explains the above mentioned classic effects. That is, **if we assume the validity of the quantum Malus law, then we can explain all the experimental results presented above in section 3**. In particular, this quantum law helps explain why half of the natural light photons (which have random directions of polarization) are absorbed by the linear polarizer and half of them passes (acquiring the polarization direction of the polarizer). Then, remembering that circularly polarized light is the normalized sum of two orthogonal linear polarizations, we also expect that half of the photons of natural light will be absorbed by a circular polarizer and half will pass through the polarizer.

4 The case of few photons

To measure the polarization of a beam of light, we compared the energies of the incident beam and of the beam emerging from a polarizer. Such a thing no longer seems possible in the case of an isolated photon, or a few single photons (although equally polarized). That is a key problem in the analysis of experimental results in cases of single photons. Here we must clarify that in the case of the Taylor experiment, photons arrived at the screen properly isolated, one by one, but it was a case of a large number of single photons. On the other hand, we can consider some situations where there is only a single photon or there are a few photons present, which are not part of a larger whole that is also involved in the process. By blocking a stream of photons-Taylor-type, and unblocking it by a very short time interval, one could strike a linear polarizer (to determine the polarization of a half dozen photons) with very few photons, some of which will be absorbed by the polarizer, and the others will go through, to be counted in the detector. Here, moreover, we must remember that the number of photons that pass a polarizer is known only on average.

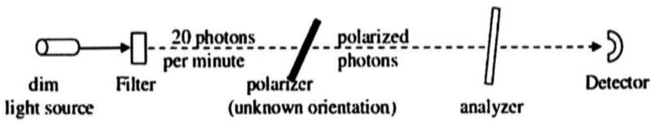

Figure 11.

That is, the photon model works satisfactorily in the case of a large number (hundreds of billions) of photons, so that the polarizers can be considered ideal, or the inaccuracies of the polarizers can be considered negligible:

i) Ideal polarizers do not reflect a fraction of the photons striking them [what real polarizers do]

ii) Properly oriented ideal linear polarizers allow to pass 100%of the incident photons, and those perpendicular to the above direction absorb all incident photons [real polarizers cannot be oriented exactly, because of practical limitations and , additionally, the uncertainty effect]

iii) Ideal polarizers have a well defined polarization direction [real polarizers, as in the case of Polaroid films the degree of its polarization depends on the quality of stretching undergone by the molecules in the chains that constitute the material], and so on.

In the case of working with few photons, besides not being possible to measure the intensity (or energy) of the incident or emerged photons, it is no longer reasonable to suppose that the above mentioned inaccuracies are negligible. This assumption solves some problems with measurements of the properties of microscopic systems.

but also creates other difficulties. For example: Assuming that there are indeed virgin photons, i.e. photons that still do not have polarization:

i) The property of being virgin photons should manifest itself also in the case of large numbers of photons, i.e., in the case of light rays. Are there virgin light rays? ,

ii) In the case of light rays it is known that there exist 'naturally' polarized rays (i.e., its polarization has not been caused by an intentional act of measurement), for example, the rays scattered by the molecules of water atmosphere,

iii) What would be a property that would distinguish virgin photons from polarized ones?. For example, an employee of G. I. Taylor tells us that in the next minute through for this window should appear some 5 or 6 photons, and you should determine if they are virgin photons or polarized photons.

[Note that the case would be different if the aforementioned partner tell us that this window will appear 5 or 6 photons per minute, and you have all the time necessary to make measurements]

We note that trying to measure the polarization of a single isolated photon is in itself meaningless, since a physical measurement requires that it be repeatable for the reason that any valid physical measurement is the result of a measurement process. Suppose (very fancy) there is actually a single photon (previously polarized but in a direction unknown to the operator) incident on a linear polarizer and then on a photo-multiplier placed after the polarizer, which:

i) indicates the presence of a photon,

ii) remains without sign of having received a photon

What can the operator conclude in each case?

i*) He can only say that the photon passed the polarizer, i.e. its direction of polarization was not perpendicular to the direction of the polarizer.

ii*) He can only say (assuming the photo-multiplier is 100%efficient) that the incident photon polarization was not parallel to that of the polarizer.

5 Polarized photons do exist

Note also that there is no doubt about the existence of polarized photons, as certified by the Experiment 2, in which all the photons in a beam of light, emerging from a first polarizar, passed a second polarizer "identical"to the first. There is also no doubt that if photons with polarization direction α strikes a second polarizer with direction β, then some of the incident photons will pass, while others will be absorbed, as certified by what we have called the Malus Law. That is, there is no doubt about the existence of polarized photons, what is at stake is the existence of virgin photons.

Suppose the following situation: Imitating GI Taylor we have produced a very weak light source, so that through a window pass (according to our calculations) some 20 photons per second. Then, just a little after the window we put a discreet linear polarizer, so we can say that, on average, from the polarizar will emerge 10 photons per second, which will strike a photo-multiplier that counts them. With this arrangement we ask some experienced physicist, call him AA, to prepare the equipment to determine the polarization of the photons that arrive at the photo-multiplier in the time interval between 9:00 h and 9:00 h + 1 second. From what is currently known, the physicist AA can not measure, in the stipulated time interval, the polarization of (approximately) some 10 photons (which emerge from the discreet polarizer). Though physicist AA says that in such a short time interval (which only allows him to count a dozen photons) he can not measure the polarization of the mentioned photons, such impossibility does not mean that these photons have no polarization. In conclusion we can state the fact that the impossibility to measure a certain property of an object (or set of objects) does not necessarily imply that that object does not possess such a property. On the other hand, if the experimenter AA were allowed to prolong his experiment with a large number of photons (say, for a few hours), then he could (orienting his polarizer-analizer to different angles and counting the number of photons passing in each orientation) determine if the photons incident on his analizer were randomly polarized, or if they were polarized in a specific direction.

In the case of experiment 3, Malus Law, we see that a large set of photons polarized in the direction α , approximately the fraction $\cos^2(\alpha - \beta)$ of them changed their polarization to the direction β. That is, the polarizer did not create the polarization of individual photons, instead they change the direction of polarization of the passing photons. [This interpretation is debatable, but without major effects for the present discussion]

Additionally, the supposed virgin photons which composed natural light, when they go through a polarizer behave as if their polarizations were randomly oriented, which is consistent with the generation of photons by atoms that are not necessarily correlated in their excitation nor in their emission instants.

Finally, consider the following set of experiments applied to a beam of intensity J.

i) We make such a ray impact on a polarizer of orientation α, finding that the emerging beam has intensity $\frac{J}{2}$. We changed the direction of the polarizer and the emerging intensity does not change. Apparently it is a ray of sunlight or a circularly polarized beam.

ii) We direct the beam to a circular polarizer, right-handed or left-handed, and we find that in both cases the emerging intensity is $\frac{J}{2}$. Apparently it is natural light.

iii) Now we direct the same ray to a rhombohedral calcite prism and get two emerging rays of equal intensity. With this result we are almost convinced that the ray in question is a ray of natural light.

But if we had done the experiment superimposing two beams of equal intensity, linearly polarized with orthogonal polarizations (but with no coherent phases) we can verify that the results of the intensities, arising from the polarizers or rhombohedral prism, would be the same as those obtained in each of the cases mentioned above. The same result would be obtained if it were no longer the superposition of two incoherent beams orthogonal to each other, but the overlap of N-incoherent-rays, with equal intensity, with polarizations oriented parallel to the diagonals of a regular polygon of N sides. The results of the mentioned experiments basically justifies the assumption that natural light photons are polarized with random polarization directions, statistically symmetrical (as long as there is no reason to suppose a preference for certain orientations).

6 Conclusions

There exist photons with definite polarization state (equivalent to a polarization direction). This can happen naturally (by effect of a natural polarizer), as mentioned in (05), or intentionally, using a polarizer.

As shown in (10), in the case of a single photon or few isolated single photons, but certainly polarized (in direction unknown to the experimenter), it is impossibl to determine the polarization of such photons, whic does not imply that these photons do not have a polar ization state before falling in the analyzer (a polarizer o a rhombohedral calcite prism).

Polarizers absorb photons or they change their po larization state, but they do not "generate" the stat of polarization (in the sense that photons acquire a po larization state just after they pass the polarizer). Th octahedron of calcite, and other crystals also change (ir two directions orthogonal to each other) the polarizatior states of the incident photons.

The postulate of the existence of virgin photons seems to have more the character of a metaphysical postulate than the character of a postulate of physics itself.

As challenges to those who maintain the existence of virgin photons:

i) Build a direct experiment showing the ability to differentiate virgin photons from photons with polarization,

ii) Explain why half of the supposed virgin photons of natural light pass through the linear or circular polarizers.

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