# Entanglement – a Resolution of the Riddle

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## Abstract

Our resolution of the entanglement riddle **dispels** the need to attribute non-locality in spacetime to Quantum Mechanics.

This resolution is based on the contention that, in contrast to current understanding, the going of an "individual" photon through a polarizer's port is **pre-determined.**

Key Words**:** Photon, Photom, Entanglement, Polarizer

## 1 Introduction

### 1.1 The Puzzling Entanglement

The entanglement of photons and other particles has been puzzling us since the year 1935, when the famous EPR paper [1] appeared. A summary of the subject appears in [2]. In this paper we relate, without losing the generality in our argumentation, only to photons.

### 1.2 "Entanglement Between Photons that have Never Coexisted"

In a recent paper [3], titled above, the puzzling is going even deeper: *Using entanglement swapping between two temporally separated photon pairs we entangle one photon from the first pair with another photon from the second pair. The first photon was detected even before the other was created. The observed quantum correlations manifest the non-locality of quantum mechanics in spacetime.*

### 1.3 Subjects Discussed in the Paper

According to Quantum Field Theory (QFT), the photon and its ground state photon - the **Photom**, as we call it – are quantized excitations of the electromagnetic field **and not** “separated” entities.

Spontaneous emission of a photon is an induced emission by a photom, that travel with the photon, and actually participates with an ensemble of identical photoms in phase.

The “probabilistic nature” of the photon (Malus Law) is related, not to its own nature, but to it entering a polarizer with an ensemble of photoms.

**All this** led us to conclude that, in contrast to current understanding, the going of an “individual” photon through a polarizer’s port is **pre-determined.**

This led us to the resolution of the entanglement long standing riddle.

## 2 The Photon in the Quantum Field Theory - QFT [4]

The fields of QFT, one for every Elementary Particle, reside in space and follow its topology. These fundamental fields, according to QFT, are all there is. The particles themselves are merely quantized excitations of these fields. As such they are point-like and structureless, and their masses cannot be derived and calculated. Necessarily and wrongly these masses are considered constants of nature. The **ground state photon (**photom as we call it) has the smallest discrete amount of electromagnetic field energy, which is 1/2hυ. The **next level of excitation,** with the energy hυ, is the **photon.** Thus, it is wrong to consider, in various situations, photons just by themselves without relating to their relevant photoms. The calculation of the density in space of photoms, which is very large compared to a single photon, appears in appendix A.

## 3 Stimulated and “spontaneous” Emission [5][6]

Fig. (1) shows on the left an atom on a high energy level (upper line) above the lower energy level (bottom line-ground state). If a photon, with the same energy as that of the difference in the energy levels of the atom, arrives it can induce the emission of an identical photon by the atom fall to the ground state. This process is termed **Stimulated Emission**.

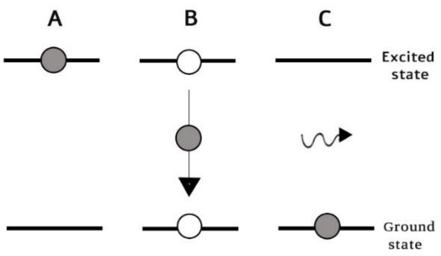


**Fig. (1) Stimulated and Spontaneous Emission**

However, the atom can also emit a photon without an inducing photon from outside. This kind of emission is termed **Spontaneous Emission.** Physicists [5], myself included, are convinced that in this case it is a photom (ground state photon) that induces the emission. Below is evidence in support of this “Spontaneous” Emission idea.

Fig. (2) shows a beam of excited atoms running through a narrow tube. The rate of emission of photons from these atoms is reduced drastically compared to their rate outside the tube – more than ten times [6]. The explanation is simple: In this tube, modes of vibrations, namely photoms, perpendicular to the tube axis and with a wavelength twice the inner diameter of the tube, cannot exist. Hence the number of photoms is drastically reduced and so is the spontaneous emission.

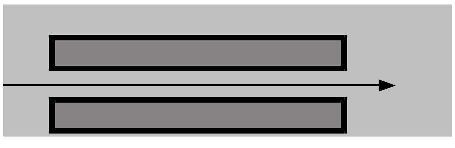

**Fig. (2) Damping Spontaneous Emission**

In another experiment a mirror is placed close and parallel to a beam of excited atoms. This time the emission rate is doubled, since the mirror reflects incoming photoms back towards the beam, thus doubling their number per unit volume.

## 4 The Probability of a single Photon to Go Through a Wire-Grid Polarizer - to be Transmitted or to be Reflected

A single Photon is never traveling by itself; it should, at-least, be followed by a single photom, with the same wavelength, that induced its emission (spontaneous emission) [5][6] and it usually travels with an ensemble of photoms moving in phase like a semiclassical wave. Hence, we must first understand the interaction of photoms with the polarizer. Note, that a polarizer changes the polarization of photons and photoms.

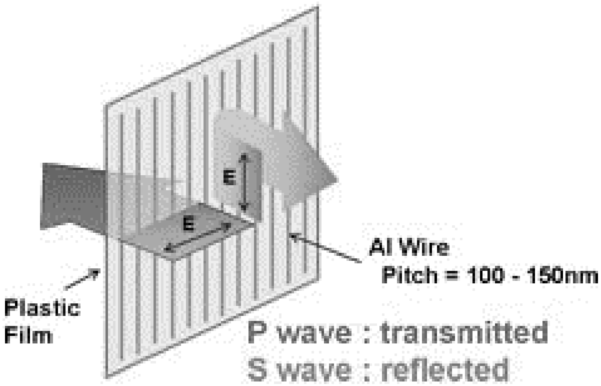


**Fig (3). Wire-grid Polarizer**

For our discussion we picked the wire-grid polarizer, see Fig. (3). In this case the mechanism by which the photons and photoms interact with the polarizer is much clearer than for other polarizers. The **Wire-grid Polarizer** explained in the Wikipedia:

*Electromagnetic waves which have a component of their electric fields aligned parallel to the wires will induce the movement of electrons along the length of the wires. Since the electrons* *are free to move in this direction, the polarizer behaves in a similar manner to the surface of a* metal *when reflecting light, and the wave is reflected backwards along the incident beam.*

*For waves with electric fields perpendicular to the wires, the electrons cannot move very far across the width of each wire. Therefore, little energy is reflected and the incident wave is able to pass through the grid. In this case the grid behaves like a* dielectric material*.*

*Overall, this causes the transmitted wave to be* linearly polarized *with an electric field that is completely perpendicular to the wires.*

The **Transmitted** wave goes through the port designated T (The Horizontal port H)

The **Reflected** wave goes through the port designated R (The Vertical port V)

We contend that in contrast to current understanding the going of an “individual” photon through a polarizer’s port is pre-determined.

## Our contention:

**A photon** with a given linear polarization oriented 0 to 45 degrees to that of the polarizer axis will be reflected - will “go through” port R (The Vertical port V).

**A photon** with a given linear polarization oriented 45 to 90 degrees to that of the polarizer axis will be transmitted - will go through port T (The Horizontal port H).

This contention complies logically with the physics of the Wire-Grid polarizer, but lucks direct experimental proof. The main justification, however, is the fact that it provides a realistic and simple resolution of the entanglement riddle – an indirect proof.

The “probabilistic nature” of the photon - Malus Law, as we show in the next chapter, is related, not to the photon nature alone, but to it entering the polarizer with an ensemble of photoms.

## 5 Malus Law

Fig. (4) shows the well-known passage of photons through a polarizer and a following analyzer. (If both the polarizer and analyzer are of the wire grid type, we can redirect the reflected beam in the forward direction. In this case we can relate to the orthogonal axes as the ports R and T.)

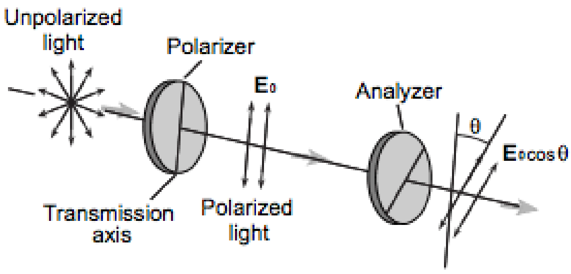


**Fig. (4) Malus Law**

We now consider (first step), **only the passage of photoms** and not that of photons.

Say n identical photoms, in phase, enter the analyzer at an angle $\vartheta$. We can assume (a classical argument) that n $\cos^2\vartheta$ of them go through the analyzer port R (the vertical port V). And $n\sin^2\vartheta$ of them go through the other analyzer's port T (the horizontal port H).

A photon that leaves the polarizer (second step of our consideration), arrives with its polarization at an angle $\vartheta$ to the analyzer. This photon follows one of the $n\cos^2\vartheta$ photoms to go through port R of the analyzer OR one of the $n\sin^2\vartheta$ photoms to go through port T of the analyzer. Hence its probability to go through port R versus its probability to go through port T is $\cos^2\vartheta$ versus $\sin^2\vartheta$. This "probabilistic" nature of the photon is the **Malus Law**.

## 6 Entanglement

In an Entanglement experiment **the successive exited atomic emissions, of two perpendicularly or parallel polarized photons, is induced by two different photoms.**

Our contention, if valid, explains without additional arguments the **Entanglement -** the going of these two photons always through different or the same ports of the two opposite polarizers – full correlation.

## 7 Summary

We reveal the nature of the interaction of light with polarizers based on standard QFT and the known fact that spontaneous emission is an induced emission by ground state photons (photoms). This enables us to resolve the entanglement riddle. **Our resolution dispels the need to attribute non-locality in spacetime to Quantum Mechanics.**

## References


[1] A. Einstein Podolsky B., Rosen N: Physical Review 47, P. 777, (May 1935)

[2] Alastair Rae: Quantum physics: Illusion or reality? Cambridge university press

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[4] R. Loudon: The Quantum Theory of Light, Oxford University Press (2000)

[5] Milonni, The Quantum Vacuum (1994) Academic Press

[6] L. E. Ballentine: Quantum Mechanics (1989), Prentice Hall p 412


### Appendix A Spatial Density of Photoms [5]

The spatial density of an ensemble of photoms of a given λ and a bandwidth dλ, see [5], is:

$n(\nu) = 8\pi\nu^2/c^3 \cdot d\nu$ but $\nu=c/\lambda$ and $d\nu=c/\lambda^2\cdot d\lambda$ hence:

$n(\lambda)=8\pi/\lambda^4\cdot d\lambda$

For photoms of $\lambda = 500$nm and a bandwidth $d\lambda = 0.5$nm the spatial density is:

$n(\lambda) \sim 2\cdot 10^{11}$ photoms per cubic centimeter.