The Double Slit Experiment Enigma - Resolved

Shlomo Barak

Taga Innovations 16 Beit Hillel St. Tel Aviv 6701716 Israel

Corresponding author: shlomo@tagapro.com

Abstract

We dispel the need to attribute a dualistic nature to single photons that arrive, in a double slit experiment, at the screen one at a time. Interference is explained in a novel way based on known and accepted physics. The photon, being an excitation of the electromagnetic field, is regarded as a particle or more accurately a wavepacket, of a defined size, and not a wave.

Key Words**:** Photons, Photoms, Electromagnetism, Interference, Space

1 Introduction

1.1 The Puzzling Dualistic Photon

Electromagnetic (EM) waves are ensembles of closely packed photons that oscillate in phase and hence are classical waves. Similarly, ensembles of closely packed ground state photons - photoms – as we call them, oscillating in phase, are also classical waves. As we show, photons and photoms condense when they are in phase and disperse when in anti-phase. These features, as we explain, resolve the riddle of the "interference" of single photons in the double slit experiment and dispel the need to attribute a dualistic nature to photons.

Note, that in modern literature [1] [2] [3] the photon is considered a wavepacket, but its shape, structure and size are not discussed.

1.2 Subjects Discussed in the Paper

Quantum Field Theory (QFT), considers the photon and its **ground state photon** - the **Photom**, as we call it – to be 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.

Space is a lattice. By attributing a cellular structure to space we can explain its expansion, its elasticity and can introduce a cut-off in the wavelength of the vacuum state spectrum of vibrations. Without this limitation on the wavelength, infinite energy densities arise.

All this led us to conclude, in contrast to current understanding, that the "individual" photon goes from its source through **one** of the slits and to the screen. This track is determined by the photom that induced its emission. And the interference pattern is that constructed by the photoms. This led us to the resolution of the long-standing interference 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 $1/2h\upsilon$. The **next level of excitation,** with the energy $h\upsilon$, 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 [3][5]

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 falling to the ground state. This process is termed **Stimulated Emission**.

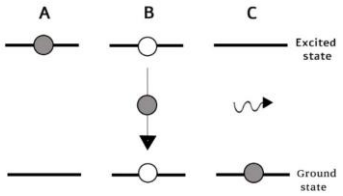

Fig. (1) Stimulated and Spontaneous Emission

The atom, however, can also emit a photon without an inducing photon from outside. This kind of emission is termed **Spontaneous Emission.** Physicists [3], 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 [5]. 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 Space

4.1 Space as a Lattice

By attributing a cellular structure to space we can explain its expansion, its elasticity and can introduce a cut-off in the wavelength of the vacuum state spectrum of vibrations. Without this limitation on the wavelength, infinite energy densities arise. The need for a cut-off is addressed by Sakharov [6], Misner et al [7], and by Zeldovich [8]. The Bekenstein Bound sets a limit to the information available about the other side of the horizon of a black hole [9]. Smolin [10] argues that:

> *There is no way to reconcile this with the view that space is continuous for that implies that each finite volume can contain an infinite amount of information*

Riemann, quoted by Chandrasekhar in Nature [11], was of the opinion that space is a lattice. Relevant review introductions appear in papers [12] [13] and [14].

4.2 Photons Photoms and the Space Lattice

The electromagnetic field follows the topology of the space lattice. Photoms and photons are wavepackets of this field – vibrating entities of it. Being attached to the space lattice, adopting its topology, it is reasonable to assume that the vibrations of the field are also the vibrations of the lattice, or even identical (unification of electromagnetism and gravitation). This idea is the key to our resolution of the enigma (we have suggested an experiment to verify this contention).

5 Condensation and Dispersion of Photoms and Photons

Fig. (3), shows a symbolic space lattice, which is like a 3D fisherman's net. Imagine that each vertical plane, in Fig. (3), going into the page, is a plane in which a photon or a photom is moving. If two adjacent photons or photoms of the same frequency oscillate in anti-phase side

by side (**Left**) they stretch the lattice horizontally and move apart to ease the tension. The result is **dispersion** - a reduced spatial density of the photons or photoms. If, however, they oscillate in phase (**Right**), they move together to ease the tension and the result is **condensation** - higher density. A similar situation occurs if they move one below or above the other.

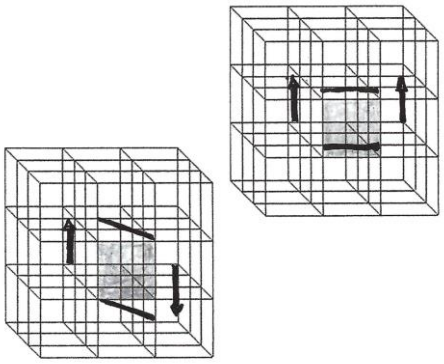

Fig. (3) Dispersion and Condensation

Photons or photoms, of the same wavelength, when they are in phase and closely packed, move as a classical wave. Let a wave front, of such a classical wave, hit the double slit; if the photons or photoms, which are coming from the two slits and hit the screen, are in phase (on the screen) they create maxima zones on the screen, and minima if out of phase. In other words; intensity is reduced in zones of **destructive** interference whereas in zones of **constructive** interference intensity is enhanced. Photons and photoms entering these zones, however, are **neither annihilated nor created** and the total energy is conserved. No annihilation or creation takes place**,** only **a spatial displacement of the particles.** Namely, a reduction in their density (intensity) in one zone and an increase in their density (intensity) in the other.

6 Interference with Individual Photons

The probability of a photon to hit a certain spot on the screen is the classical probability of the inducing photom to arrive at this same spot. But the photoms arrive as a classical wave and

hence their unseen interference pattern on the screen. This explains the many, one at a time, photon accumulation effect that builds the interference pattern.

This dispels the need to attribute a dualistic nature to photons and solves the collapse issue of the "wavefunction" (although there is no such thing for a photon).

This wave of photoms is actually the **De Broglie guiding wave**. In the year 2011 it was shown [15] in a "Weak- Experiment" [16] that a single photon, in the Double Slit experiment, goes all the way from the source to the screen through only one slit. The photon follows a trajectory known as the **D. Bohm trajectory** [17]. Our "mechanism" by which the photon is "guided" is also relevant to other elementary particles, atoms, molecules, and even microscopic bodies.

7 Summary

No need to attribute a dualistic nature to single photons that arrive, in a double slit experiment, at the screen one at a time. Simple argumentation based on known and accepted physics resolves the enigmatic experiment.

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References

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

[2] G. Grynberg, A. Aspect and C. Fabre: Quantum Optics, Cambridge (2010)

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

[4] R. Feynman: QED, Princeton press (1985)

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

[6] A. D. Sakharov: Soviet Physics-Docklady, Vol. 12 No. 11, P.1040 (1968)

[7] Y. B. Zeldovich and I. D NOVIKOV: Stars and Relativity (1971) P. 71

[8] C. W. Misner, K. S. Thorne, J. A. Wheeler: Gravitation, (1970) P. 426 P. 1202

[9] J.D. Bekenstein.: Phys. Rev. D 7, p. 2333 (1973)

[10] L. Smolin: Three Roads to Quantum Gravity (2001)

[11] S. Chandrasekhar NATURE 344, 285 (1990)

[12] G. Amelino-Camelia: arXiv: astro-ph/0201047 (4 Jan 2002)

[13] D. Finkelstein: Quantum time, on the web (2010)

[14] R. Penrose: The Road to Reality Knopf N.Y. (2005)

[15] Steinberg et al: Science, 332(6034), 1179-1173, (2011)

[16] Y. Aharonov, et al: PRL 60, pp1351, (1988)

[17] Philippidis, Dewdney and Hiley: Il Nuovo Cimento, Vol. 52B, N1, P. 15 (1979)

Appendix A Spatial Density of Photoms [3]

The spatial density of an ensemble of photoms of a given λ and a bandwidth $d\lambda$, see [3], 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 λ = 500nm and a bandwidth $d\lambda$ = 0.5nm the spatial density is:

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