Complete Explanation for the Double-Slit Interference-Experiments

By:

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Abstract

The particle-interference-experiments, with the photons and electrons have clearly shown that they are always detected as localized 'particles'; and the density of their detections exhibit a pattern similar to the interference of waves. This experimental-observation is now *explained* here, making the current, 'probabilistic interpretation', a past history. The 'particle' is first mathematically characterized as an 'impulse function' in space; and then Fourier-transformed into the wave-number-domain, as a wide band of constituent-waves as shown in the fig. 1&2. The 'particle' is explained as an 'event' of constructive-superimposition of a wide band of 'pre-quantum-waves'. This 'event' occurs in space at regular distances; and at regular instances in time. We know that even the purest monochromatic laser source has a 'line-width' of a few Giga-Hertz, or at least a few kilo-Hertz. So in the particle-interference-experiments, they are these wide bands of waves which pass through both the slits, even in the case of single photon states, and interfere physically. This physical interference of the wide bands of pre-quantum-waves determines the position and time of emergence of the 'particle'. Thus, form the theoretical view-point, there are only the waves, and waves alone; and the 'particle' is a specific situation of constructive-superimposition of all the spectral-components of pre-quantum-waves; so there is no wave-particle-duality.

Key Words: Quantum mechanics, Wave-particle-duality, Fourier transform

1. Introduction

The wave-particle-duality of the photons and the electrons; their complementarities; Max Borns probabilistic interpretation of quantum-mechanical waves; Einstein's dissatisfaction, expressed in the words: "God does not play dice"; Broglie-Bohme's pilot-waves, Feynman's method of path-integral…are well known to the readers. Einstein's statement that: "My constant brooding for two decades has brought me no closer to the answer, what is the photon. Some rascals think, they know; but they are deluding themselves." This statement shows the gravity of the puzzle. Also, according to Feynman: "The double-slit interference-pattern of particles is the biggest puzzle of science."

In a previous paper [1] it was explained that at the frequencies of light, very narrow-band filtering, and generation of purely monochromatic light, of one Hz bandwidth, are not technically possible; so there is always some bandwidth and 'line-width', due to which the waves form wave-packets, localized in space, as 'particles'. Now this letter resolves the puzzles of wave-particle-duality and double-slit interference experiments. It starts with the experimentally observed fact that photons and electrons are always detected as 'whole', 'un-split' 'particles'. These 'particles' are always localized in a point-like space. So, they are mathematically characterized [2,3,4] as an impulse-function in space. This 'impulse-function', when Fourier-transformed, yields a wide band of waves, termed here as 'pre-quantum-waves', to distinguish them from the de-Broglie's matter-waves, and the quantum-mechanical-waves. The 'particle' of light or matter is not a substance; rather it is an 'event' of constructive-superimposition of the wide band of 'pre-quantum-waves'. In the double-slit-experiments, they are the 'pre-quantum-waves' which interfere physically. The interference of a very wide band of 'pre-quantum-waves' emerging from two different slits cause a change in the place of constructive-superimposition of them, detectable as the 'particle'. Thus, from the theoretical insight emerging from this letter, we can say that there are only the 'pre-quantum-waves' which interfere physically; and there is no theoretical uncertainty at the fundamental level. Since our instruments can detect only the 'particles', whose place of emergence depends of superimposition of a very wide band of 'pre-quantum-waves' arriving at a point from different directions, we are currently able to predict only the probability of their detection in a given volume-element.

2. Description

Since the ‘particle’ is always detected at a point-like place, it can be mathematically characterized as an impulse-function in space as shown in fig.1. Now we can Fourier-transform this impulse-function from the space-domain into the wave-number-domain, as shown in the bottom of the fig.1. This wide band of waves of the fig.1,(Bottom) imply that the ‘particle’ contains a very wide band of ‘pre-quantum-waves’.

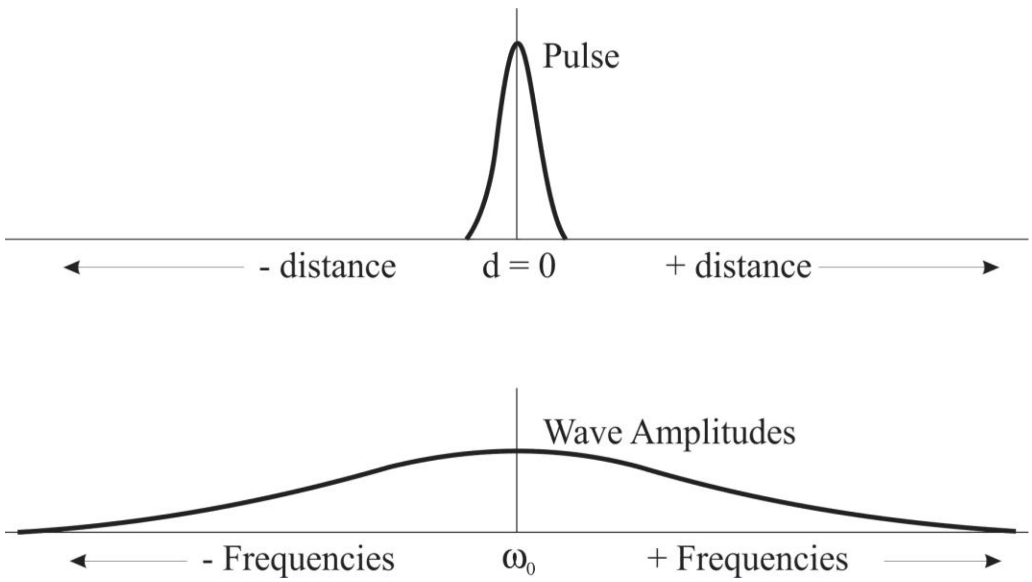

Fig.1: A ‘particle’ mathematically represented as a ‘pulse-function’ (top); and its frequency-domain-representation (bottom).

If we want to convert this wide band of waves back to the impulse, then we will have to constructively-add all the spectral-components of the wide band, having a specific phase-relationship. Of course, in the real world situation, we can expect only a reasonably-wide band of frequencies; so the ‘particle’ has to be somewhat bigger in size and volume, than the theoretical and mathematical zero volume.

We know, that monochromatic laser light is used for the ‘double-slit interference experiments’. And we also know that even the purest sources of laser light has a ‘line-width’ and bandwidth of a few Giga-Hertz, or at least a few Kilo-Hertz. The figure-2 shows a superimposition of only eight spectral components.

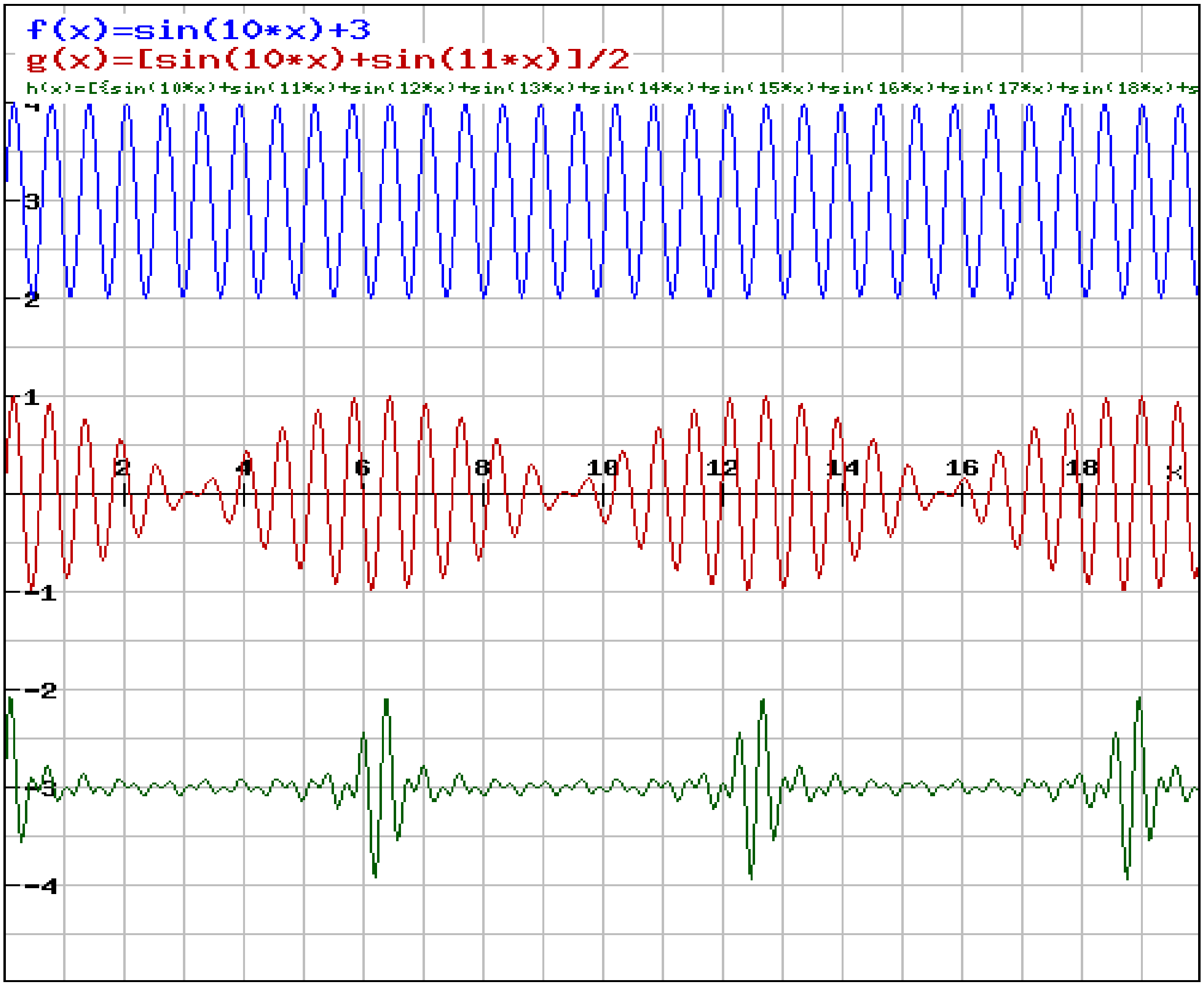

Fig.2: Figure showing 'waves' becoming 'particles': As we add more and more spectral components, they go on getting localized, like the 'particles'. (i) Blue curve, on the top, shows a wave of purely single frequency, Sin (10* x); (ii) the red curve, in the middle, shows that when two waves get added, their amplitude start varying in space and time; and (iii) the green curve, at the bottom, shows that when so many waves of slightly different frequencies get added, e.g: sin(10*x)+Sin(11*x)+sin(12*x)+sin(13*x)+sin(14*x)+sin(15*x)+sin(16*x)+sin(17*x)+sin(18*x), then they coherently add only at discrete places in space and time; and mutually nullify their amplitudes at other points in space and time. Such packets of waves, formed due to superimpositions of a wide band of waves, appear to us as the 'particles'.

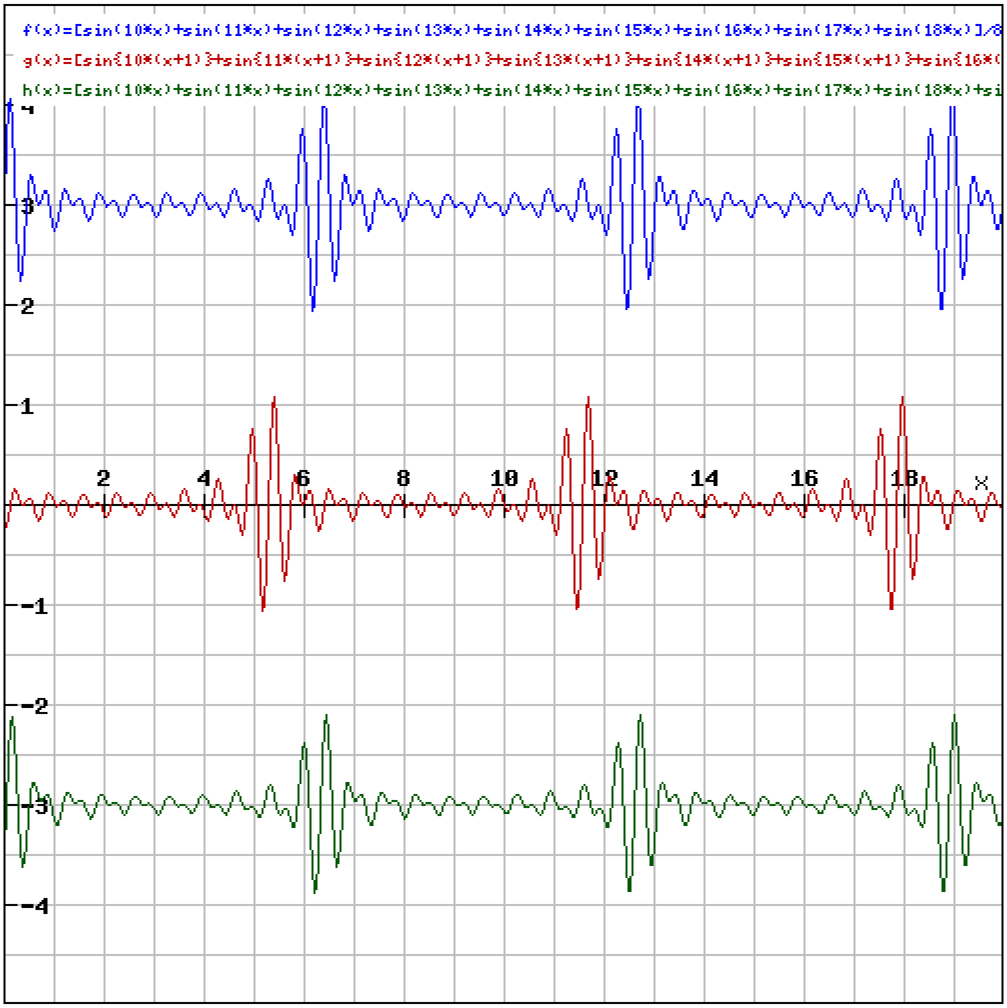

Fig.3: The blue curve on the top showing the sum of spectral components, emerging from slit-1: [sin(10*x)+sin(11*x)+sin(12*x)+sin(13*x)+sin(14*x)+sin(15*x)+sin(16*x)+sin(17*x)+sin(18*x)]/8+3.

The red curve in the middle showing the sum of phase-shifted spectral components emerging from slit-2:

[sin{10*(x+1)}+sin{11*(x+1)}+sin{12*(x+1)}+sin{13*(x+1)}+sin{14*(x+1)}+sin{15*(x+1)}+sin{16*(x+1)}+sin{17*(x+1)}+sin{18*(x+1)}]/8

And the green curve at the bottom showing the sum of further phase-shifted spectral components, due to their path-lengths, re-combining and forming the 'particles' at discrete places and time.

[sin(10*x)+sin(11*x)+sin(12*x)+sin(13*x)+sin(14*x)+sin(15*x)+sin(16*x)+sin(17*x)+sin(18*x)+sin{10*(x+6.2)}+sin{11*(x+6.2)}+sin{12*(x+6.2)}+sin{13*(x+6.2)}+sin{14*(x+6.2)}+sin{15*(x+6.2)}+sin{16*(x+6.2)}+sin{17*(x+6.2)}+sin{18*(x+6.2)}]/16-3

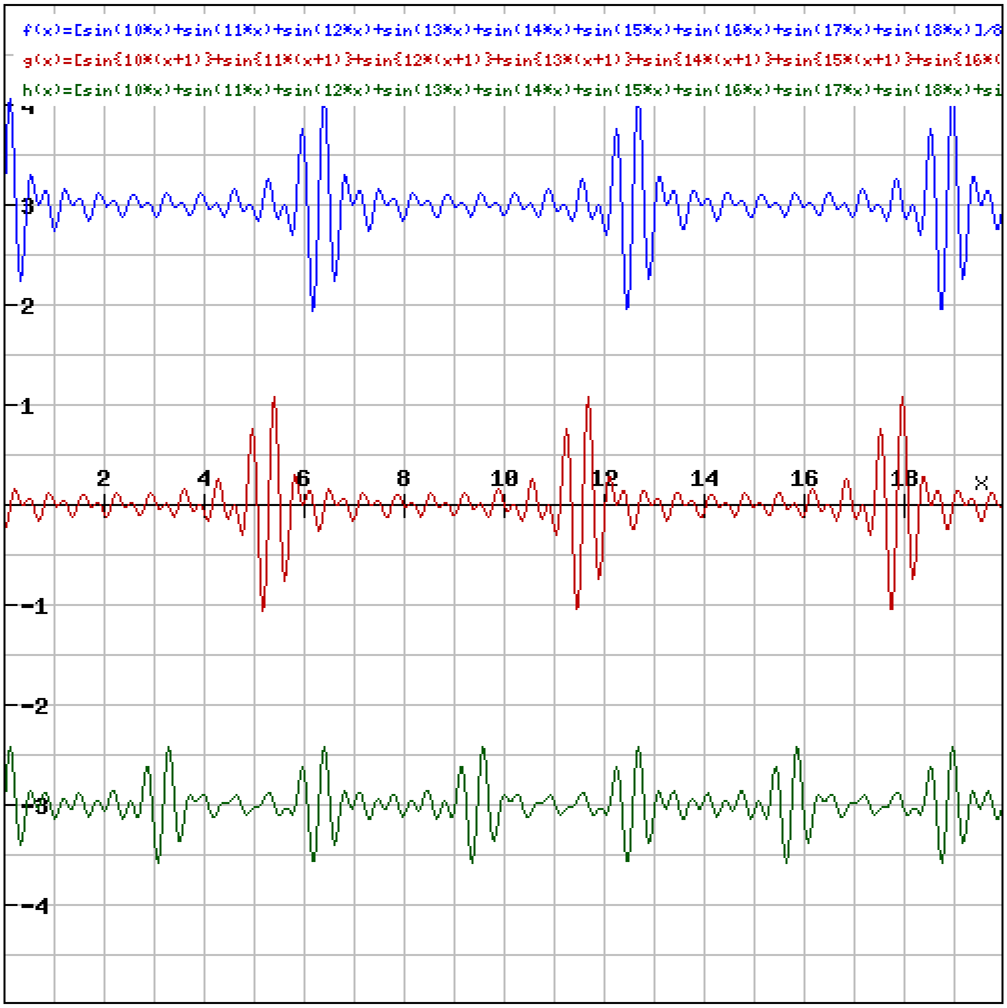

Fig.4: When the path-lengths for the waves emerging from two different slits are unsuitable for coherent superimposition, then their sum remains below threshold.

This discussion shows that the ‘particle’ of light or matter is an ‘event’ of constructive-superimposition of a very wide band of ‘pre-quantum-waves’. So when this wide band of waves is made to pass through two near-by slits, the output waves, from both the slits, experience ‘interference’. Both the slits behave as if they are the sources of the band of waves; spreading waves in all the radial directions. These two sets of wideband-waves, from the two slits, interfere constructively only at discrete points in space and time.

In the case of interference-experiments with light, the slit-widths are comparable with mean-wavelength of light; but in the case of matter-waves, their de Broglie wavelength is much larger than the wavelengths of the band of ‘pre-quantum-waves’. So the path-lengths keep differing from event to event. It was indeed a lucky coincidence for Prince Louis de Broglie, Davisson and Germer, that their experiments showed interference effects, though the slit-widths selected based on de Broglie wavelength were much larger than required!

Conclusion:

Since, even the best available laser-sources of light have line-widths of some kilo-Hertz, the double-slit interference-experiments performed so far contained a wide band of waves, whose constructive superimposition occurs only at discrete points in space and time, forming the 'photons'. Even in the case of single photon states, the wide band of waves pass through both the slits; and wherever and whenever all the spectral components of the whole band gets constructively superimposed, the 'photon' gets detected. Similar is the case with the electrons; and all other massive particles.

Discussion:

It is quite possible that this conclusion may not be the final step. But, as we published proposals of Max Born, Broglie-and-Bohme, and Feynman, in spite of objections from great scientist like Einstein, the publication of this proposal will give opportunity to readers to think further.

References:

[1] Explanation for the observed 'Wave/Particle-Duality' of Light viXra.

[2] Lathi, B. P. Communication Systems, Oxford University Press, 1998.

[3] Tank, H. K. "Some expressions of gravity without the big '*G*'" *Astrophysics and Space Science* (2011) **336**, Issue 2, pp 345-346

[4] Tank, H. K. "Some expressions of gravity without the big *G* and their possible wave-theoretical explanation" *Progress in Physics*, vol. **1** (2013) pp 3-6