# Proposed Explanations for: (i) the Wave-Particle-Duality of Light and Matter and (ii) Double-Slit-Interference of Single Photons

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**Abstract**

This letter attempts to propose explanations for the ninety-year-old puzzle which thousands of physicists, including Einstein, Plank, Feynman …have been trying to resolve. A 'particle' is first mathematically characterized here as an impulse-function in space; and then Fourier-transformed into wave-number-domain; showing that a 'particle' contains a 'set' of waves, and not just a single frequency. Then a small 'set' of waves is taken and its sum is plotted showing that at most of the places the wave-amplitudes mutually nullify each-other and constructively add only at discrete points in space and time; agreeing with our mathematical characterization. Then we show that in the experiments performed so far the red lasers had sizably wide line-width, means the sources have producing a wide set of waves, and just a pure single frequency. Similarly, in the single-particle interference-experiments incandescent filament-lamps were used with green filters inserted to isolate single photons; but it is obvious that at the frequencies of light very narrow-band-filters are not yet technically feasible, so the green filters used allowed sizable wide band of waves. These wide band of waves passed from both the slits, interfered like waves, and whenever and wherever they got coherently added, a 'particle' called 'photon' got detected.

## Introduction

Sir Isaac Newton, based on his first law of motion, had presented an argument, that the straight-line motion of a ray suggests that light must be in the form of 'particles'. But the experiments by Huygens, Fresnel… demonstrated 'wave' nature of light. Then, to explain 'black-body-radiation-curves', Max Planck proposed that light seems to be in the form of 'quanta', of energy $h\nu$. Einstein used this 'quanta' of light to explain 'photo electricity'; and won the Nobel Prize. Prince Louis de Broglie proposed a wavelength associated with every 'particle' of matter, which Davisson and Germer experimentally proved to be true. Debate continued for decades, whether light and electrons are ‘waves’ or ‘particles’. Ultimately, currently it is mutually agreed that light is both, ‘wave’ as well, as ‘particles’; but at a given moment it is either detected as ‘wave’ or a ‘particle’; there is mutual exclusiveness at the time of detection; and both ‘wave’ and ‘particle’ descriptions are ‘complementary’ to full description of light. So, currently, the physicists believe in the wave-particle-dual nature of light, and all other ‘elementary particles’. Albert Einstein once told: “Twenty years of brooding has brought me no closer to the answer, what is the photon. Some rascals think, they know, but they are deluding themselves.” Here, in this paper, an explanation for this long sought problem is proposed, that: at the very high frequencies, of the order of 400-700 nm, generation and filtering of purely mono chromatic light is technically not yet possible; so in the experiments performed so far, there has been quite a wide bandwidth involved. Typical line-width of mono-chromatic laser is of the order of Giga-Hertz to a few kilo-Hertz. So the coherent super-imposition of all the spectral-components, contained in the band, take place at discrete points in space and time. This is the reason why the experiments performed so far [Ref.-0] showed ‘particle’ nature of light. If electromagnetic radiation were always in the form of both ‘particles’ as well as ‘waves’, then even at radio frequencies we should see ‘particles of radio-waves’, in addition to the radio-waves seen on oscilloscopes.

**Preparatory Discussion:**

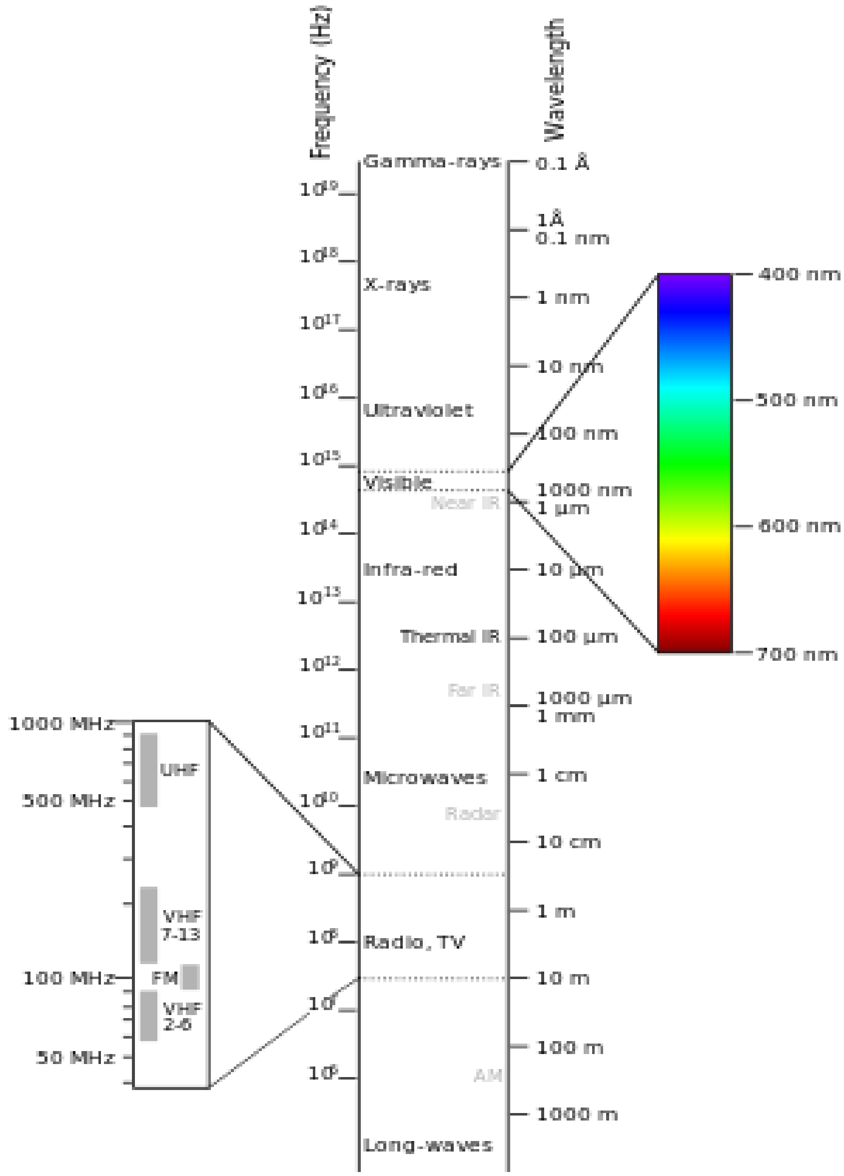


Fig.1: The electromagnetic spectrum

We know, that 'light' is a small band of the electromagnetic spectrum, as can be seen from the fig. 1: But in the experiments, always a 'particle', known as 'photon', is detected; which is localized in a very small region of space. So it can be mathematically represented as an impulse-function, shown in fig.2 below: [1-3]

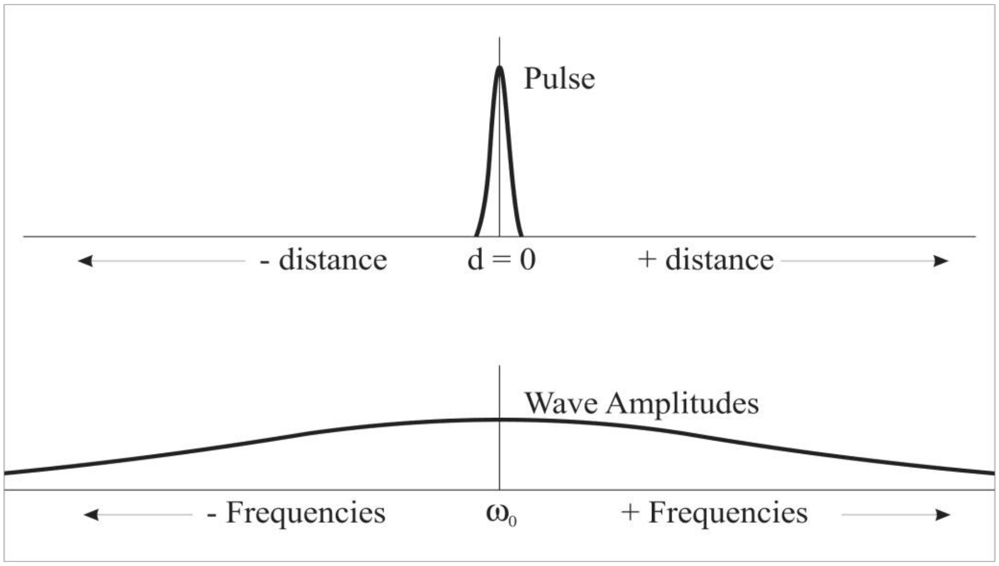


Fig.2: A single photon can be mathematically represented as an impulse-function (top), which can be Fourier-transformed as a wide band of frequencies (bottom). So a ‘particle’ called ‘photon’ contains a wide band of frequencies.

If we take a small, narrow, band of the total spectrum, then we get a ‘wave packet’ as shown in fig.3 below, as was done by inserting green filter in the single-photon-interference-experiments described in ref-0:

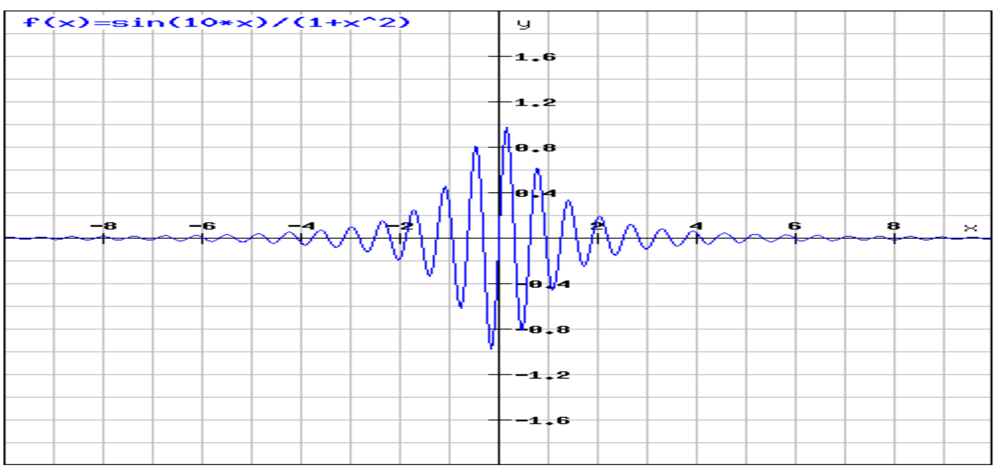


Fig.3: A small, narrow band, taken from the total wide band of the electromagnetic spectrum, looks like a wave-packet in the time domain.

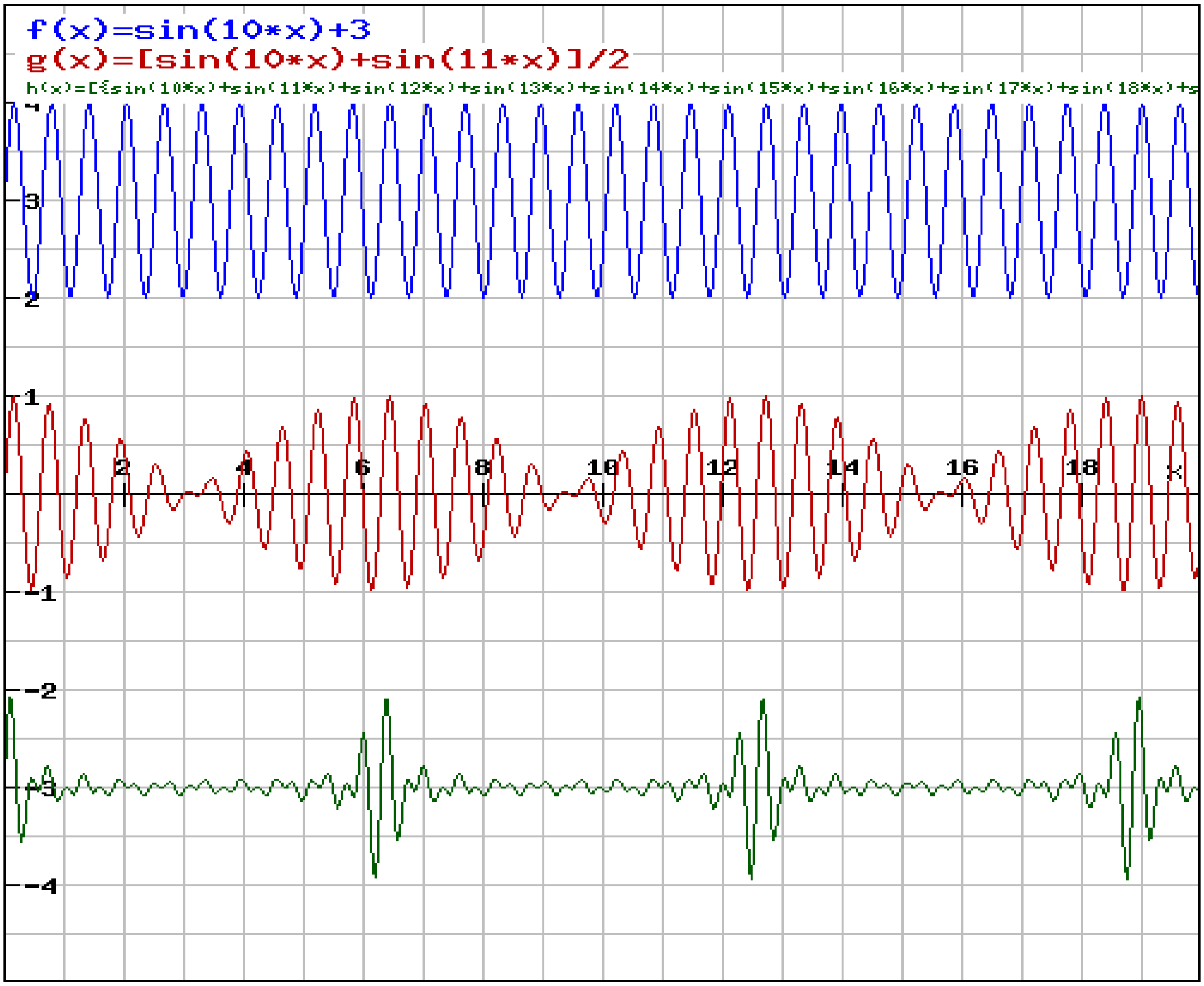


Fig.4: (i) Blue curve, on the top, shows a wave of purely single frequency, Sin (10* x); (ii) the red curve, in the middle, shows that when two waves get added, their amplitude start varying in space and time; and (iii) the green curve, at the bottom, shows that when so many waves of slightly different 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’.

**2. Explanation for the observations of 'wave-particle-duality':**

Physical experiments performed on light, for example, the experiment of photoelectric effect, contained quite a 'band' of frequencies [Ref-0], not just a single frequency; so in the time-domain, and in the space-domain, it must have been like the 'wave packet' shown in fig.3 and 4; and not a continuous wave. Therefore, it was a localized pulse, in the space domain. The light emitting atoms emit such pulses. And high intensity of light means more number of atoms emitting such pulses. At the high frequencies, like those of light, it is not possible to get very narrow-band filters, so there is always some 'line-width' of every source of light; and so we observe localized pulses in the time and space domain. But at radio frequencies narrow-band filters are possible, so we can see low-frequency-electromagnetic-waves as 'waves'; and not as 'particles'. If electromagnetic radiation were always in the form of 'particles', then even at low frequencies we should see 'particles' and not the 'waves' like radio waves, seen on oscilloscopes.

**References:**

[0] http://www.teachspin.com/brochures/Two%20Slit.pdf

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[3] 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