What needs to be known about the 'Collapse' of Quantum-Mechanical 'Wave-Function'

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Abstract

Quantum mechanical wave function predicts probabilities of finding a 'particle' at different points in space, but at the time of detection a particle is detected only at one place. The question is: how this place gets decided, and can be predicted. To seek answer to this, we assume here that a 'particle' has some "diameter", in stead of being a 'point-particle' of mathematical zero dimension; and depending upon the relative velocity between this particle and observer, its "diameter" experiences 'Relativistic length-contraction'. Then we Fourier-transform this 'length-contraction' in 'space-domain' into 'spectral-expansion' $\Delta\omega$ in 'frequency-domain', and find that momentum of a particle can be expressed as: $m\, v = h\, \Delta\omega / 2\, \pi\, c$, and de Broglie's wavelength, $\lambda_B = 2\, \pi\, c / \Delta\omega$; as was derived in [ref.1 and 2. In the ref-2 it was shown that: in fact it is the 'expansion of spectrum' in the frequency-domain, which is the physical-cause for the Relativistic length-contraction.] Then we notice that the frequency-domain translation of the particle's length in space-domain has a continuous spectrum; i.e. it contains a set of frequencies ranging from ω_{max} to ω_{min} . Therefore, as we found in ref. [3], this wide set of waves coherently add only at discrete points in space, and mutually nullify their amplitudes at rest of the places. And the place at which all the spectral-components of the wide band of waves will add constructively, will depend on the relative phase of all the spectral components. It is proposed here, that we need to know the relative phase angles of every spectral-component contained in the wide set of waves contained in the expanded wide band, for predicting the exact place of detection of the 'particle'.

Key Words: Quantum mechanics, Collapse of q-m wave, Fourier-transform

Detailed Description:

Let us take a particle, say, electron, with its rest-mass m_0, its energy, at rest, is $m_0\, c^2$, and angular-frequency, $\omega_0 = 2\pi\, m_0\, c^2 / h$, where h is Planck's constant. And its Copmton-wavelength, at rest is:

$\lambda_{C0} = h/\, m_0\, c$. Let us assume that this particle has some 'diameter', in stead of the theoretical and mathematical zero dimension. So, a 'particle' can be mathematically characterized as a 'pulse-function' in the 'space domain'; and can be Fourier transformed into wave-number-domain, as a wide 'continuous band' of wave-numbers, and frequencies. Now, when an observer with a relative velocity v approaches this electron, it finds its diameter shrunk, its energy increased from $\hbar\, \omega_0$ to $\hbar\, \omega$, and its mass increased from m_0 to m. When the diameter of the particle shrinks, its spectrum in the frequency domain will expand. To find out the amount of expansion of the spectrum, let us consider as follows: We know, that a particle's momentum, is not just a difference of above two energies, ω and ω_0 , rather, as it was first discussed in ref.1, the relationship among the 'energy-momentum-four-vectors' of the Special Theory of Relativity is: $(m\, c^2)^2$ - $p^2\, c^2 = (m_0\, c^2)^2$, so we can express this relation as a right-angle-triangle of the fig.1-a below, whose three sides are also related similarly. Since they add like vectors, the three sides of the right-angle-triangle can also be viewed as vectors, as shown in the fig.1-a. Now, we know that communications-engineers represent electric-signals like Sin $w\, (t)$ and Cos $w(t)$ as rotating 'vectors'. Similarly, we can translate the vectors of the fig.1-a as 'signals' of frequencies shown in the fig.1-b.

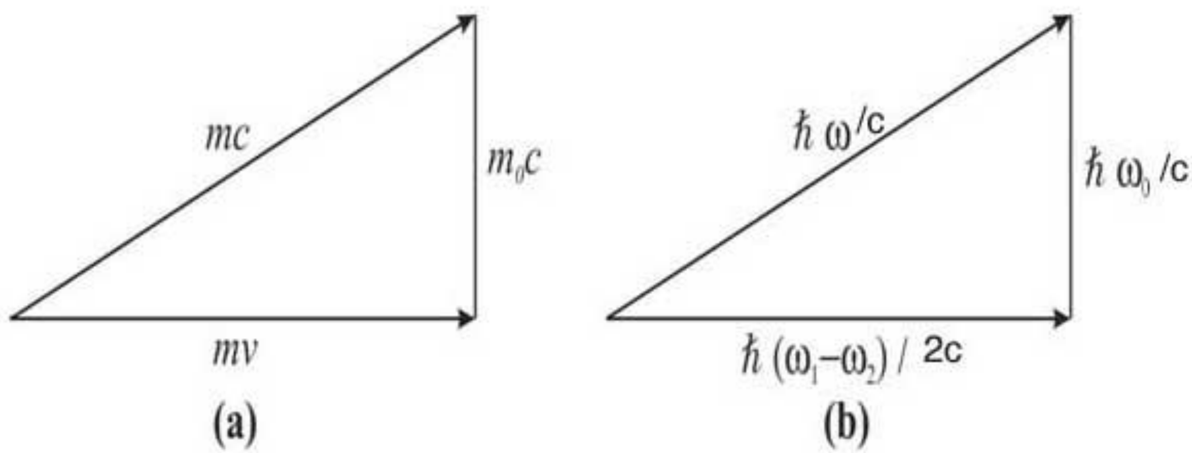

Fig.1:(a) Geometric representation of energy-momentum-four-vector of the special relativity; and (b) its wave-theoretical-translation. Since the frequencies ω_0, ω, and $\Delta\omega$ actually represent the center-frequencies of wide bands of waves, and there is no coherence between them, they are getting added like addition of two wide bands of noise, which also get added as: $N_{total} = [(N_1)^2 + (N_2)^2]^{1/2}$. (In the figure:1-a, the horizontal vector $m\, v$ represents the magnitude and direction of vector-sum of three components of momentum $m\, v_x$, $m\, v_y$ and $m\, v_z$).

Now, by using Planck's relation, E = $\hbar\, w$, and Einstein's relation, E = $m\, c^2$, we get the relations: $m\, c^2 = \hbar\, w$; therefore, $m\, c = \hbar\, w/c$, $m_0\, c = \hbar\, w_0 / c$, and :

For the momentum, $m\, v = m_0\, v \,/\, (1- v^2/c^2)^{1/2}$

i.e. $m\, v = m_0\, v\, c \,/\, (c^2 - v^2)^{1/2}$

i.e. $m\, v = (\hbar\, w_0/2\, c) \, [\, 2\, v \,/\, [(c - v) \,(c + v) \,]^{1/2}$

i.e. $m\, v = (\hbar\, w_0 \,/\, 2\, c) \,[\, \{(c + v) / (c - v) \}^{1/2} - \{ (c - v) / (c + v) \}^{1/2} \,]$

i.e $m\, v = [\{ \hbar\, w_0 \{(c + v) / (c - v) \}^{1/2} \} - \hbar\, w_0 \{ (c - v) / (c + v) \}^{1/2} \,] / 2c$ ....(1)

We can write w_1 for the term, $w_0 \{(c + v) / (c - v) \}^{1/2}$, and we know that w_1 is a longitudinally Doppler-shifted frequency, when the source of light of frequency w_0 '*approaches'* the observer with a relative-velocity *v*. Similarly, we can write w_2 for the term, $w_0 \{ (c - v) / (c + v) \}^{1/2}$, and we know that w_2 is a longitudinally Doppler-shifted frequency, when the source of light of frequency w_0 '*moves away'* from the observer with a relative-velocity *v*. So, we can write:

$m\, v = [\, \hbar\, w_1 - \hbar\, w_2] \,/\, 2c$, as shown in the figure: 1(b)…………………………..……(2)

The expression-1 can be interpreted as follows: We can consider a 'particle' of 'matter' as a 'standing-wave' formed by a combination of two waves traveling in opposite directions with a velocity *c*. The wave traveling in the forward direction gets Doppler-shifted such that:

$w_1 = w_0 \{(c + v) / (c - v) \}^{1/2}$; and for the wave traveling in the opposite direction, we should take (-*c*) for *c*, so the Doppler-shifted-frequency $w_2 = w_0 \{ (c - v) / (c + v) \}^{1/2}$. Thus we can express the momentum of a particle as $m\, v = [\, \hbar\, w_1 - \hbar\, w_2] / 2c$. Similarly, we can express the 'energy' of a moving 'particle' as $E = [\, \hbar\, w_1 + \hbar\, w_2] / 2$. …...(3)

This discussion leads us to physical interpretation of De-Broglie's 'matter-wave' as '*envelop-variations'* of the combined wave, composed of two waves of frequencies ω_1 and ω_2 traveling in opposite directions, as shown in the graphs below. And 'energy' of a 'moving-particle' is the '*summation of energies'* of the two constituent-waves traveling in the opposite directions and initially having half of the rest-mass-energy.

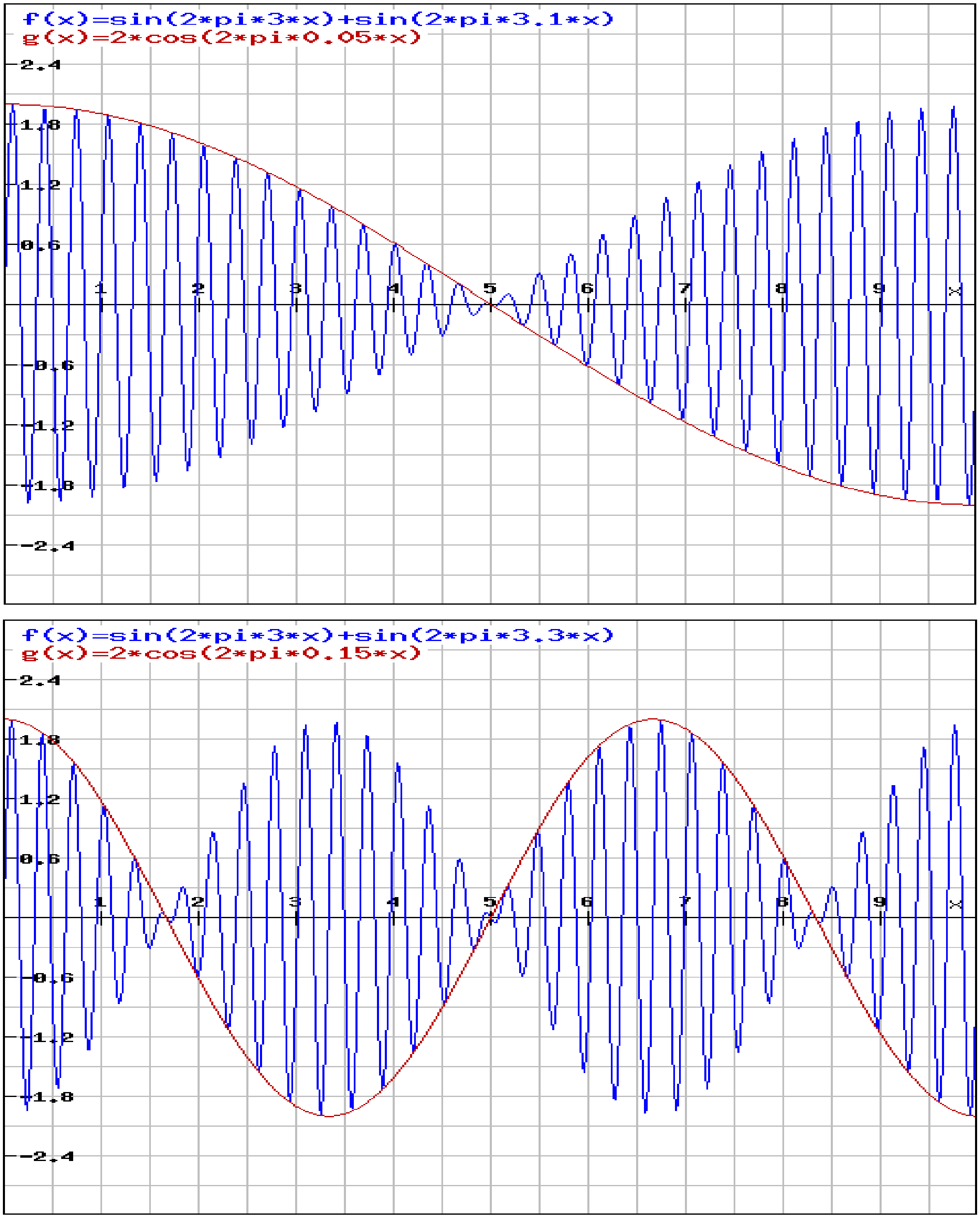

Fig.2: The waves in blue color showing superimposition of two Doppler-shifted-waves; and the wave in red-color, showing envelop-variations of the superimposed-waves, which we have been knowing as the de Broglie's 'matter-wave'. As the difference between the two Doppler-shifted-waves increases, as shown in the second figure, the de-Broglie-wavelength goes on reducing.

Emerging insight into the de-Broglie's 'matter-waves':

The wavelength of de-Broglie's 'matter-waves' is conventionally expressed as:

$\lambda_B = h / m v$.

Now, based on the expression-1:

$\lambda_B = 2 h c / [\hbar w_1 - \hbar w_2]$ ……………………………………………………………..(4)

From the expression-4 we find that de-Broglie-wavelength is a 'distance between the two constructive-superimpositions of the two Doppler-shifted constituent-waves' of frequencies ω_1 and ω_2, as shown in the fig. 2 , red curves. But, from the mathematical characterization of the 'particle', and its Fourier transform we know that the frequencies ω_0 , ω_1 and ω_2 are center-frequencies of wide bands. So, the physical 'wave' associated with a moving 'particle' is: *the sum of two 'sets of waves' of center-frequencies ω_1 and ω_2*. Therefore, a particle is detected at the place where: *all the spectral-components of the two 'sets of waves' of center-frequencies ω_1 and ω_2' add constructively*. And, as was explained in ref.1, and shown in the fig.3 below, constructive superposition of a wide band of waves takes place at discrete places in space forming a 'particle' from the set of 'waves'. The de Broglie's wave, which is an envelope of superposition of just two waves, of center-frequencies, ω_1 and ω_2, is only able to give 'probabilities' of detections of the 'particle'; because it does not contain information of phase-angles of each and every spectral component contained in the wide bands.

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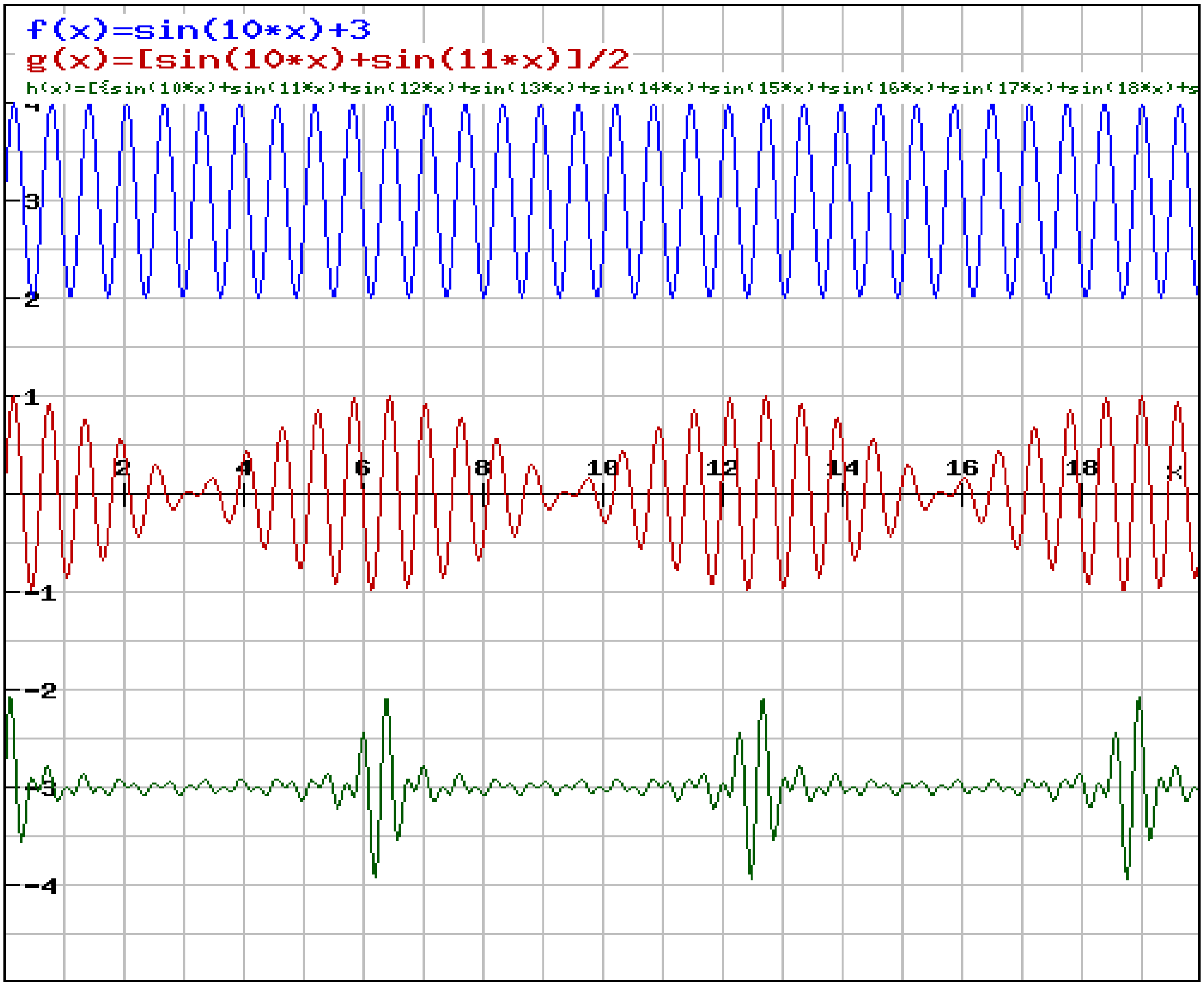

Fig.3: (i) Blue curve, on the top, shows a wave of purely single frequency, Sin (10* x); (ii) the red curve, in the middle, shows that when two waves get added, their amplitude start varying in space and time; and (iii) the green curve, at the bottom, shows that when so many waves of slightly different 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, are detected by the detector as the 'particles'.

Conclusion:

Now we know that a 'particle' contains a '*band'* of frequencies, instead of only one frequency

w_0. So the Doppler-shifts discussed by us are actually the shifts of the whole '*bands*' of the frequencies. And w_0, w_1 and w_2 are just 'mean-values' of the wide bands. In the double-slit-interference-experiments, we can expect 'detection' of the 'particle' at the place where the spectral-components of these two whole *bands* emerging from the double slits get added constructively, and not where just the amplitudes of single de-Broglie-wave; as is expected currently. Thus we need to know phase-angles of each and every spectral-component, contained in the wide bands of waves, for predicting the exact place of detection of the 'particle'.

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