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 a 'diameter' equal to its 'Compton-wavelength', and depending upon the relative velocity between this particle and observer, its Compton-wavelength 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 my previous paper [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 set of waves, contained in the expanded band $\Delta\omega$, 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 band by $\Delta\omega$, for predicting the exact place of detection of the 'particle'.

Detailed Description:

Let us take a particle, say, electron. Its rest-mass is, say, 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: $\lambda_{C0} = h / m_0 c^2$.

Let us assume that this λ_{C0} is the 'diameter' of the electron.

So, a 'particle' can be mathematically characterized as a 'pulse-function' of width λ_{C0} 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, from λ_{C0} to λ_C, its energy increased from ω_0 to ω, and its mass from m_0 to m .

When the diameter of the particle shrinks from λ_{C0} to λ_C , its its spectrum in the frequency domain will expand. To find out the amount of expansion of the spectrum, let us consider the following:

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: $(m\, c^2)^2 - p^2\, c^2 = (m_0\, c^2)^2$. We can express this relation as a right-angle-triangle of the fig. 1-a below, whose three sides are also related similarly. 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' shown in the fig. 1-b.

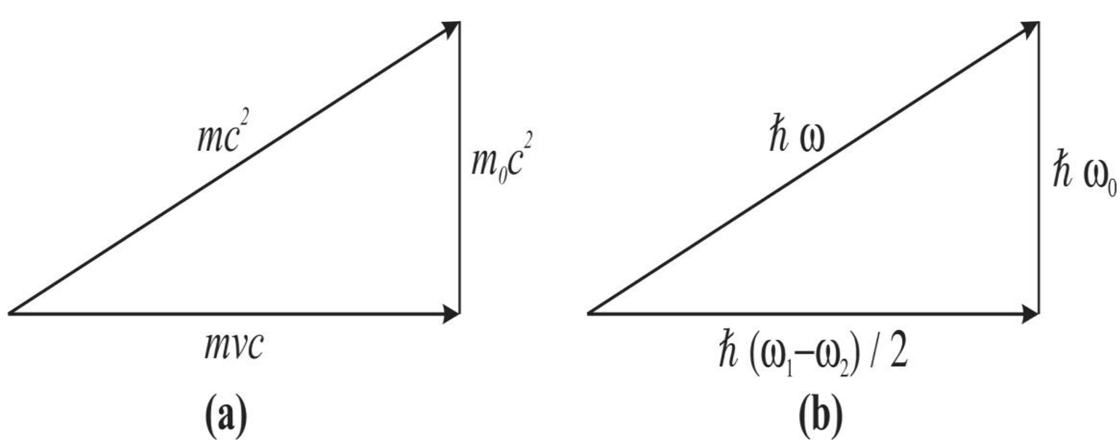

Fig.1:(a) Geometric representation of energy-momentum-four-vector of the special relativity; and (b) its wave-theoretical-translation. Since these frequencies are spread in wide bands of waves, and there is no coherence between them, they are getting added like addition of two wide bands of noise, which 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 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.

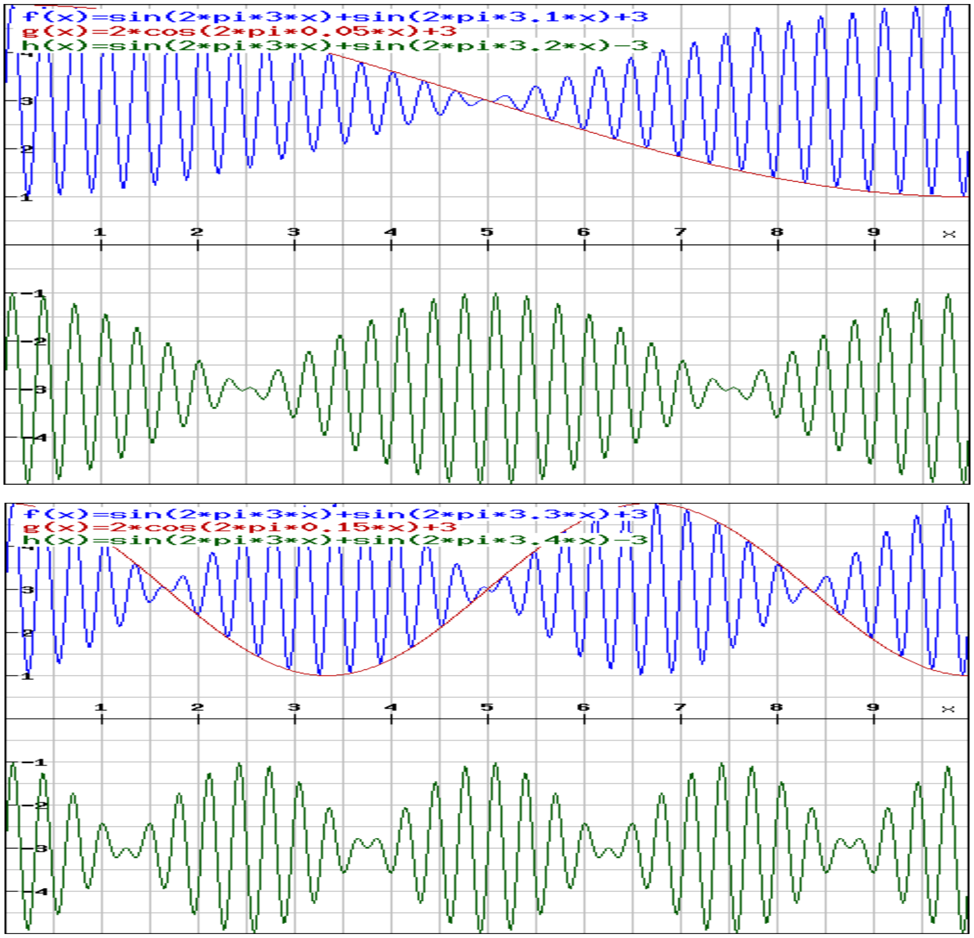

Fig.2: The waves in blue and green colors showing superimposition of two Doppler-shifted-waves; and the wave in red-color, showing envelop-variations of the superimposed-waves, which we have been knowing as the de Broglie's 'matter-wave'. As the difference between the two Doppler-shifted-waves increases,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

Some insight into 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', as shown in the fig. 2 .

Moreover, as we find from the Fourier-transform of the pulse-function, of width λ_C , a 'particle' is a *band* of frequencies, ω_0 and ω considered by us so far, are center-frequencies of the two wide bands.

Conclusion;

Now we know that a 'particle' of 'matter' is actually a spherical wave-packet. So, it contains a bell-shaped '*band'* of frequencies, instead of only one frequency w_0 so far considered by us. 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.

So, we can expect 'detection' of the 'particle' at the place where the spectral-components of this whole *band* emerging from the double slits get added constructively, and not just the amplitudes of single de-Broglie-wave, as is expected currently.

.References:

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