Explanations for the Observations of: (i) 'wave-particle-duality' of 'Light', and (ii) the 'Cosmological red-shift'

By

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ABSTRACT

It is well known, that in some experiments, light exhibits 'wave' property; like interference and diffraction; whereas in other experiments, like photoelectric effect, it shows 'particle' nature. So, the physicists currently think in terms of 'wave-particle-duality' of light, their mutual exclusiveness, and complementarily. Here, in this paper, this 'wave-particle-duality' is 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'. Then this familiarity with waves is applied to understand the observations of 'cosmological red shift'.

Key Words: Wave-particle-duality, Cosmological red shift, Fourier transform

1. Introduction:

Sir Isaac Newton first 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 they are 'waves' or 'particles'. In the nineteen nineties, Partho Ghose and Deepankar Home attempted to experimentally verify whether they are 'waves' or 'particles', but their results showed that light is both, 'wave' as well, as 'particles'; but at a given moment it is either detected as either '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 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.

The 'cosmological red shift' is understandable as follows. We know that the star-light received on earth is a vector-sum of electric and magnetic fields emitted from more than one atom. Light from each atom propagates as waves in the form of concentric circles. Since there is a space-distance between emitting atoms, there is a phase-difference between those waves. So, the vector

sum of the waves from more than one source gets phase shifted. And the cumulative phase alteration resulted due to multiple sources is observed as the ‘cosmological red shift’ as described in section-4.

2. Preparatory discussion:

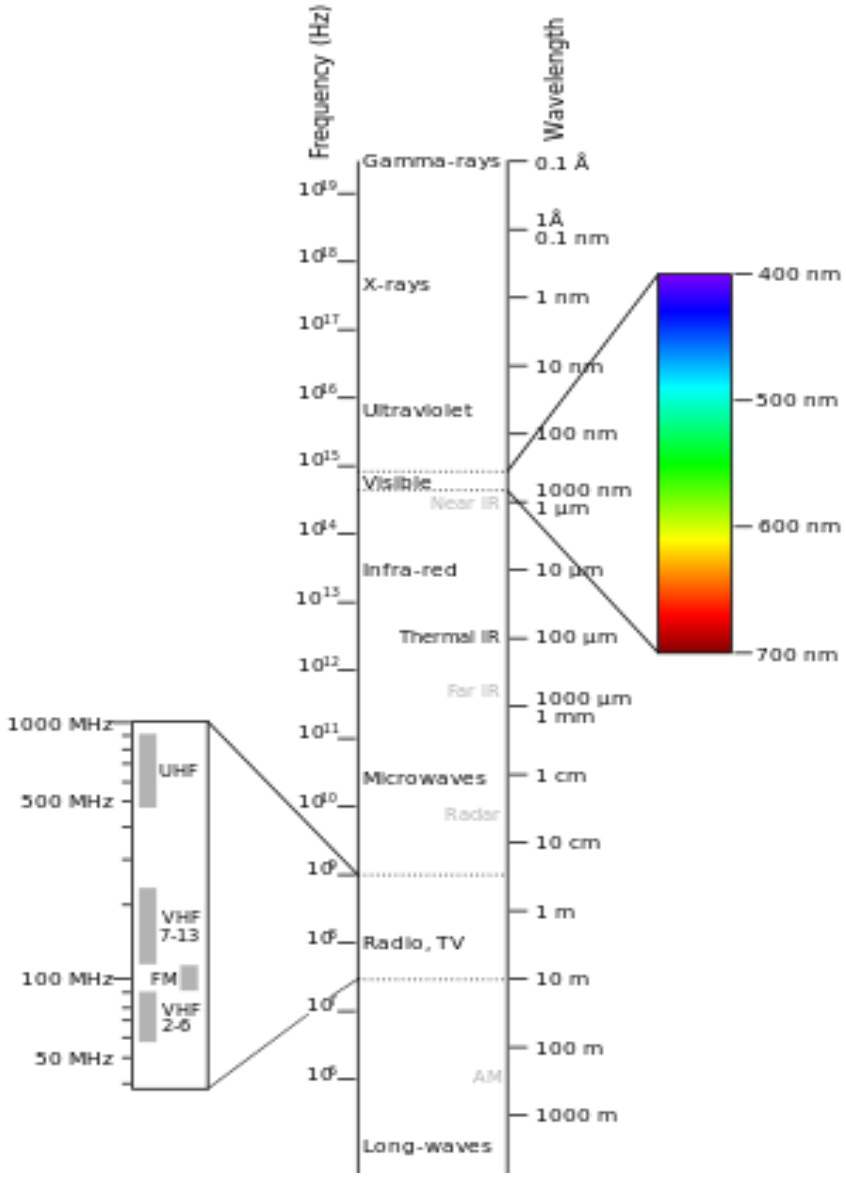

Fig.1: The electromagnetic spectrum

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: (Lathi 1998, Tank 2011, 2013)

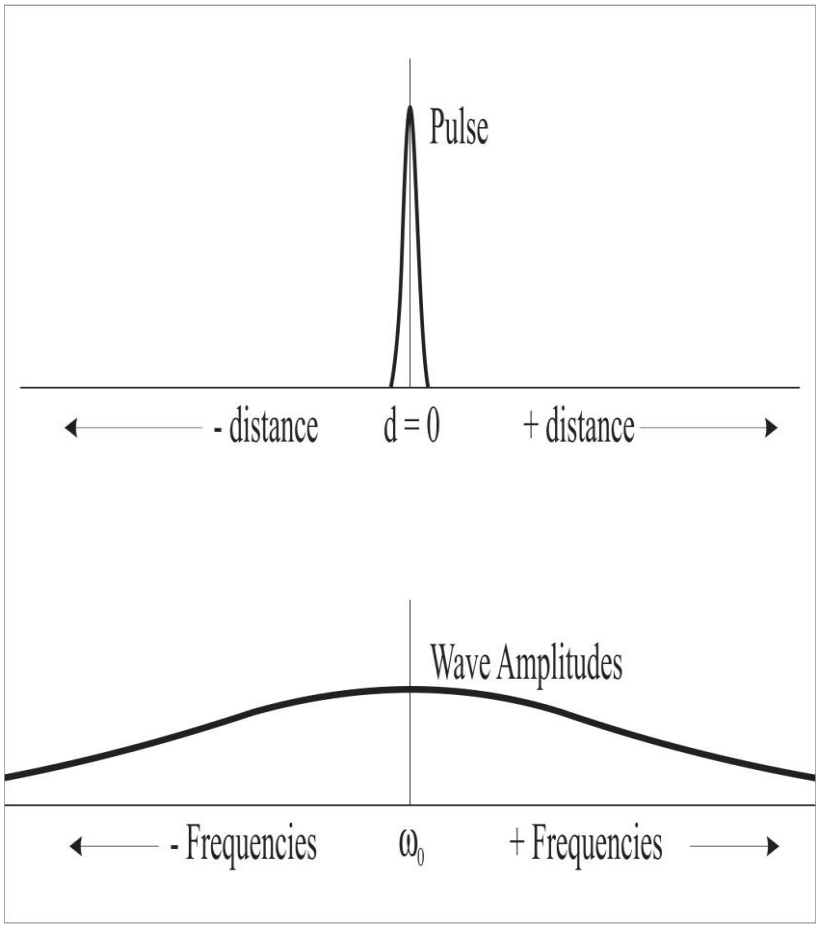

Fig.2: A single photon can be mathematically represented as impulse-function (top), which can be Fourier-transformed as a wide band of frequencies (bottom). So a ‘particle’ called ‘photon’ contains a wide band of frequencies.

If we take a small narrow band, of the total spectrum of the fig.2 (bottom), then we get a ‘wave packet’ as shown in fig.3.

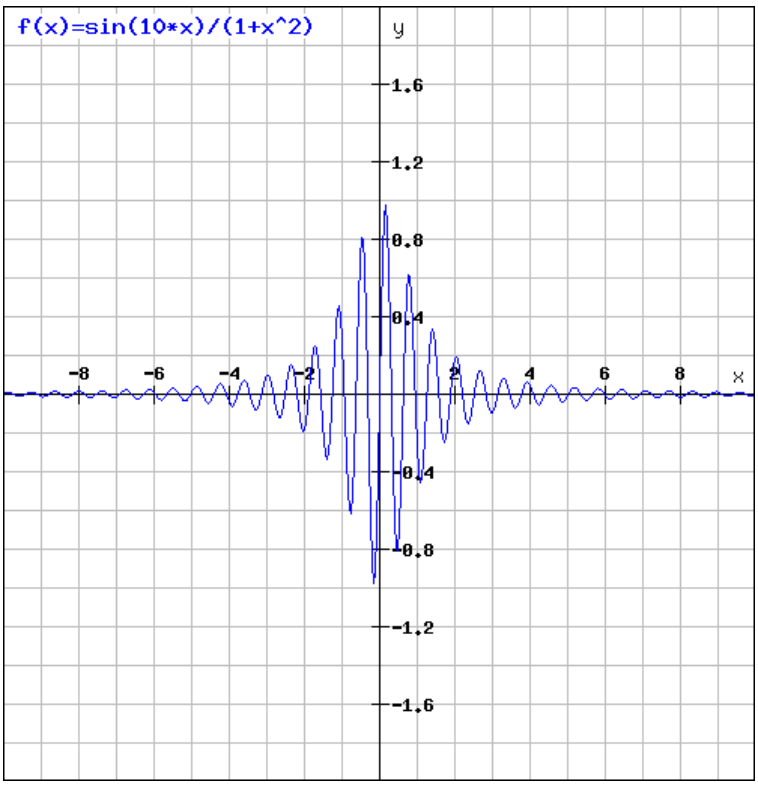

Fig.3: A small, narrow band, taken from the total wide band of the electromagnetic spectrum, looks like a wave-packet in the time domain.

3. Explanation for the wave-particle-duality:

Physical experiments performed on light, for example, the experiment of photoelectric effect, must have contained quite a 'band' of frequencies, 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 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.

4. Explanation for the ‘Cosmological Red Shift’:

We know that the star-light received on earth is a vector-sum of electric and magnetic fields emitted from more than one atom. Light from each atom propagates as waves in the form of concentric circles as shown in fig.4. Since there is a space-distance between emitting atoms, shown as source-1, source-2, source-3 in the fig.4, there is a phase-difference between those waves.

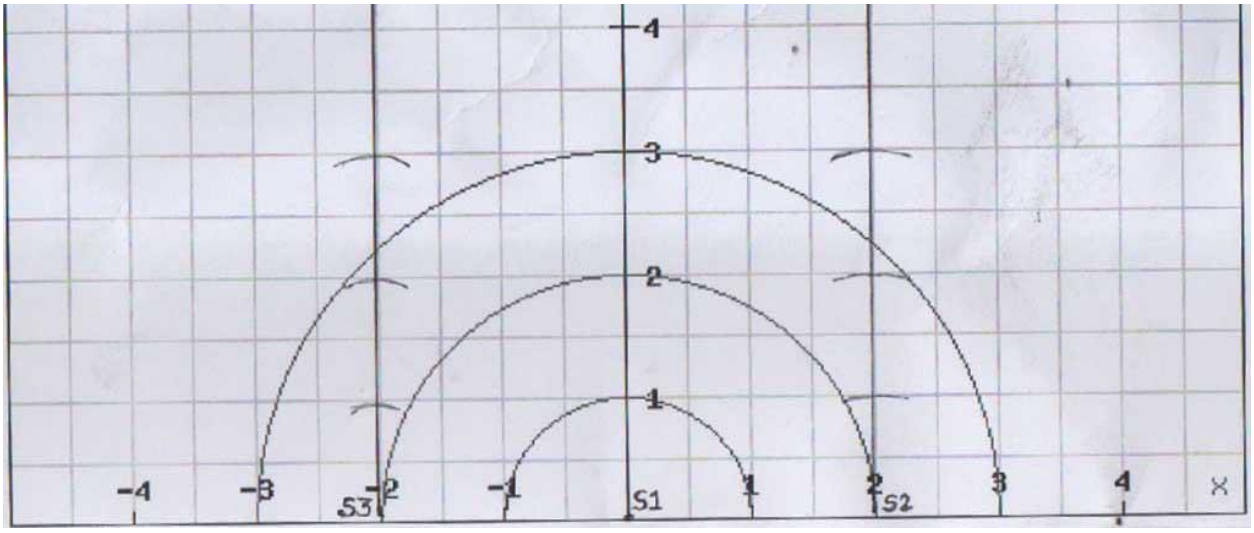

Fig.4: Showing peaks of electric fields from the source-1 at x = 0. There are two more sources of the same frequency and wavelengths located at x = 2 and x = -2 , generating electric fields like S-1.

Let us imagine that the electric field from the source-1 is a horizontal vector of 2 cm length; and electric field from source-2 is a vector at minus thirty degrees, and of 2 cm length. So, the vector sum of the two waves gets phase shifted by some angle theta. As these waves will progress in the y-direction, there will be different amounts of phase difference at different points; and different amounts of resultant phase of their superimposition at different points. And the

cumulative phase alteration resulted due to multiple sources at different distances is expected to be the cause for the 'cosmological red shift'; as observed by Perlmutter (1999) and Riess (1998).

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