

Explanation for the observed 'Wave/Particle-Duality' of Light

By



Hasmukh K. Tank

Indian Space Research Organization

22/693 Krishna Dham-2, Vejalpur, Ahmedabad-380015, India

e-mail: tank.hasmukh@rediffmail.com, hasmukh.tank1@gmail.com

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'.

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

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 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 monochromatic 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.

Preparatory Discussion:

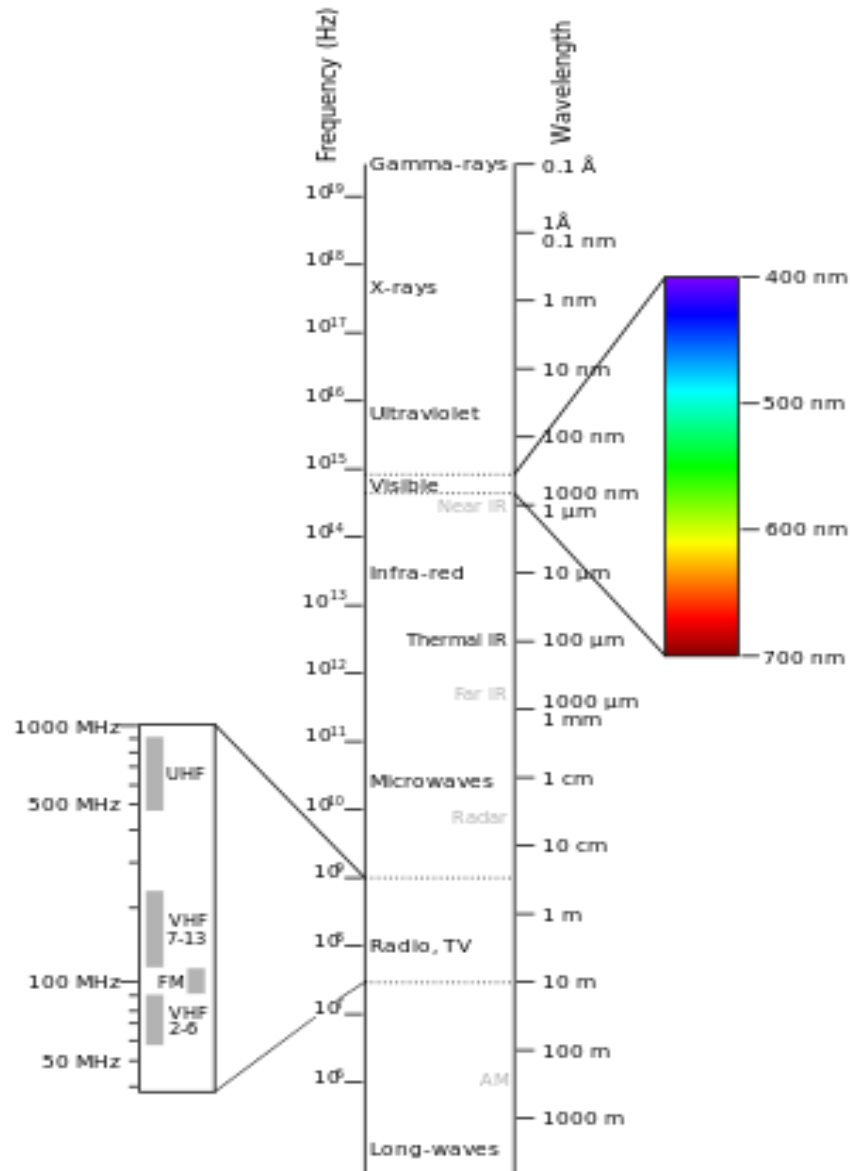


Fig.1: The electromagnetic spectrum

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]

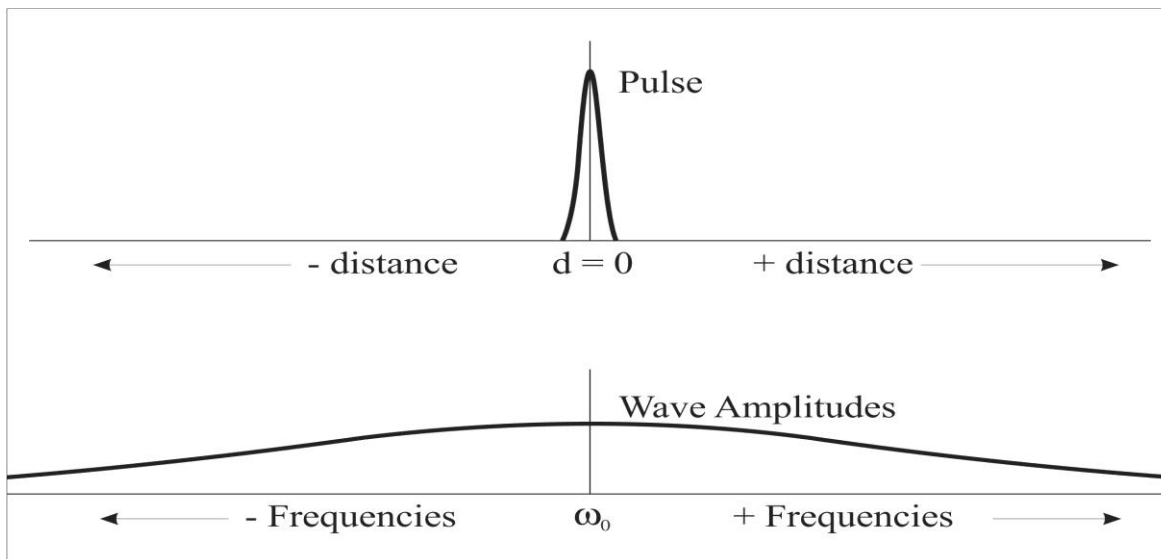


Fig.2: A single photon can be mathematically represented as an impulse-function (top), which can be Fourier-transformed as a wide band of frequencies (bottom). So a ‘particle’ called ‘photon’ contains a wide band of frequencies.

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

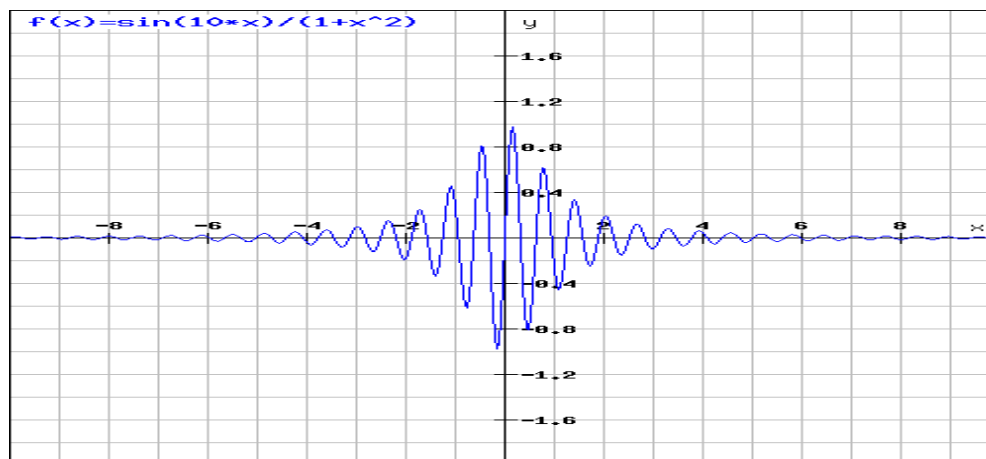


Fig.3: A small, narrow band, taken from the total wide band of the electromagnetic spectrum, looks like a wave-packet in the time domain.

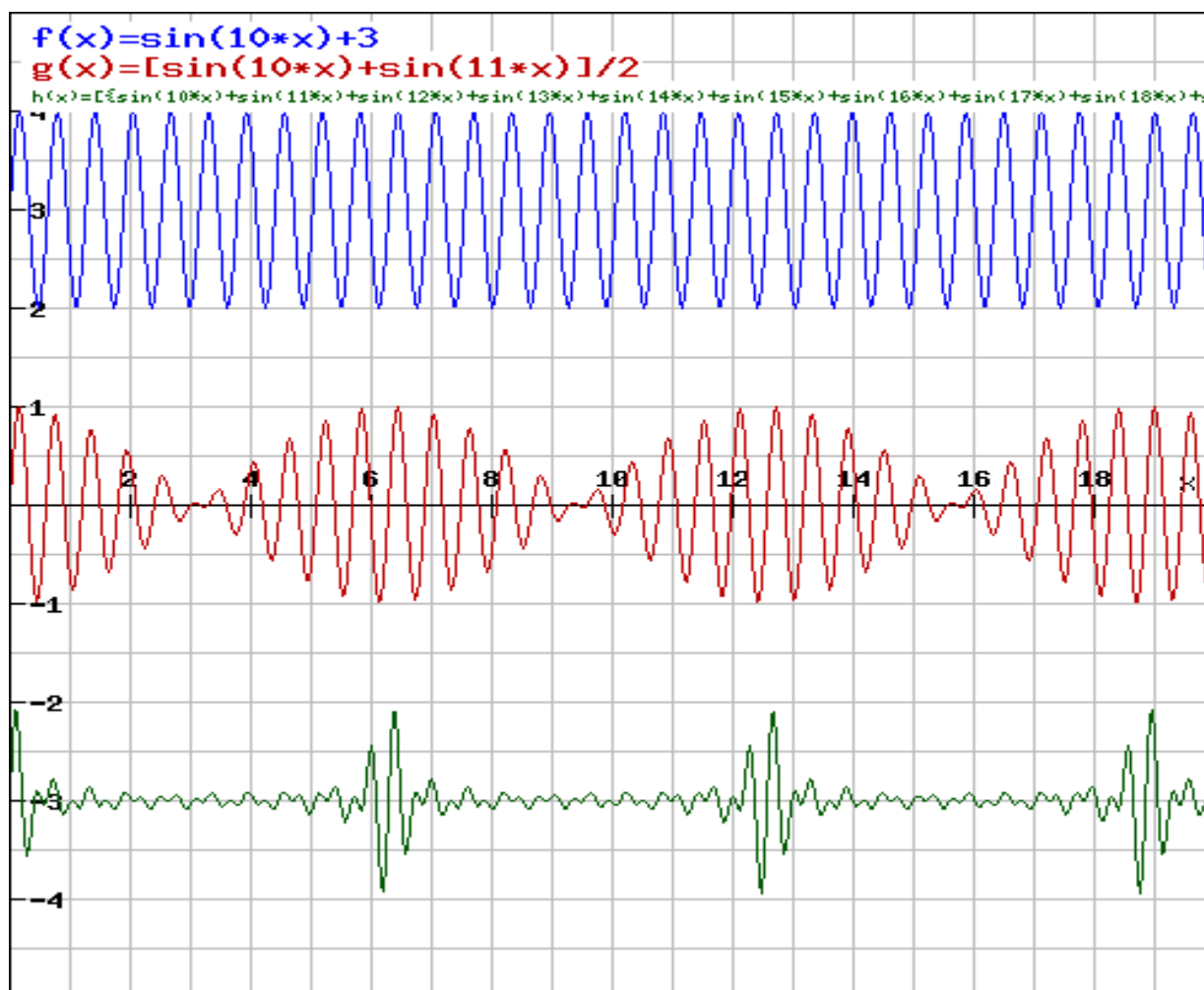


Fig.4: (i) Blue curve, on the top, shows a wave of purely single frequency, $\sin(10 \cdot x)$; (ii) the red curve, in the middle, shows that when two waves get added, their amplitude start varying in space and time; and (iii) the green curve, at the bottom, shows that when so many waves of slightly different frequencies get added, e.g: $\sin(10 \cdot x) + \sin(11 \cdot x) + \sin(12 \cdot x) + \sin(13 \cdot x) + \sin(14 \cdot x) + \sin(15 \cdot x) + \sin(16 \cdot x) + \sin(17 \cdot x) + \sin(18 \cdot x)$, 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, 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 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.

With this explanation, humanity has now reached a conclusion that: every thing and being in this universe is composed of waves, and waves alone. It may be interesting at this juncture to recall, that in a spiritual book written before many centuries, titled Yoga Vashishtha Maha Ramayana, the teacher Vashishtha explains to Prince Rama, that:

Vishvam Bichi-Vilasaha Ayam, Cit-Sudha-Abdhe Udeti Yaha !

Vileeyate Cha Tatra-eva, Madhye Katham Tad-Maya !!

Meaning: This universe is a play of waves, arisen in a nectar-ocean of the ultimate reality; it also subsides in that ocean alone; so, in its present state of waves also, it is nothing but a manifest form of the ultimate reality alone!

References:

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