

Can a deeper understanding of the measured behavior of light remove wave-particle duality?

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Abstract

Our starting platform is the staggering and pervasive successes of the Huygens-Fresnel principle (HFP) from macro to nano photonics fields, which model the propagation as if each point on the wave front serves as a secondary point source. Summation of the complex amplitudes of these secondary wave fronts with proper inclination factor gives us remarkably accurate results for every possible realistic situation. Therefore, we take the concept of secondary point source of “energy” as a reality in all of cosmic space, irrespective of whether the space is “empty” or filled with “materials” as we understand them. It amounts to accepting the existence of an all pervading cosmic tension field (CTF). We justify our platform by comparing and contrasting with the various “material” based propagating waves that we can generate and experience, which always require the existence of uniform tension field energy at every point. Then we show that two of the key motivations behind Dirac’s quantization of the EM field can easily be accommodated by semi-classical model a la Jaynes (quantized atoms and classical EM wave packet). They are: (i) Photo electric effects that require photon to be indivisible packets of energy; and (ii) QM transition rule requiring the emission of a unique frequency ν would violate “monochromaticity” rule implied by Fourier’s time-frequency theorem and “coherence theory” if photons were to be time-finite classical wave packets.

Key Words: Wave particle duality, Nature of cosmic medium, Cosmic tension field.

1. Remarkable accuracy of HF diffraction model

Let us carefully revisit the implications of the staggering successes of the Huygens-Fresnel principle (HFP) giving the prescription as to how to model the propagation of a wave. It prescribes that we should consider every point on a propagating wave front experiences a source of tension field (energy) that facilitates the generation of secondary spherical wavelets. Summation of these complex amplitudes with proper inclination factor provides the accurate model for the propagation of the waves. In the field of EM wave propagations, from radio to X-rays, through macro structures and media to nano strictures and waveguides, we have yet to find any violations of the predictions from this simple prescription. When the HFP prescription is framed mathematically with the constraints imposed by the wave equation and classical causality, we get the following equation [1] well known to students of optics:

$$U(P_0) = \frac{-i}{\lambda} \iint_{\Sigma} U(P_1) \frac{\exp(ikr_{01})}{r_{01}} \cos \theta \, ds \quad (1)$$

The field $U(P_0)$ at a point P_0 at a point r_{01} from a point on the aperture Σ is derived as the sum (superposition integral) of all the “secondary” complex amplitudes generated by the incident wave front $U(P_1)$. Rigorously speaking, purely from the logic of conservation of

energy, no signal in this universe can have infinitely long extension either in space or in time. Incident $U(P_1, t)$ and received $U(P_0, t)$ signals are time finite, time evolving:

$$U(P_0, t) = \frac{-i\nu}{c} \iint_{\Sigma} U(P_1, t) \frac{\exp(i2\pi\nu t)}{r_{01}} \cos\theta \, ds; \quad t = (r_{01}/c) \quad (2)$$

Further, we have replaced λ by ν and r_{01} by $t = (r_{01}/c)$. The purpose is to underscore that since light has a finite velocity, the secondary wavelets from various points on Σ arrives at different times at different points r_{01} on the observation screen. Therefore, diffraction patterns, in general, must be time varying and would build up with time for any realistic light signals [2].

The core concept of HFP was established before Maxwell formulated his celebrated wave equation. After the development of Maxwell's wave equation for EM waves and rigorous mathematical framework for wave propagation (Green's function) along with physically justifiable boundary conditions and inclination factor, the relation given by Eq.1 has turned out to be remarkably accurate for all situations explored so far. If HFP is so accurate, why can't we declare it as the actual physical model ("law") of light propagation through free space and all media? The key problem is that we have not been able to explicitly model and verify a physical source of tension energy in the free space that facilitates the generation of secondary wavelets.

Let us underscore a behavior of light waves that indicate the existence of assistance by some all-pervading tension energy that help us re-direct energies of EM waves with passive components. Regular transmission gratings, grating-like transmission Fresnel lenses, simple curved lenses all can re-direct the energy of EM waves as new wave fronts (convergent, divergent or collimated) without the need of any energy provided to the EM field through these transmissive components. Extremely high intensity focused spot of sunlight that can vaporize metal or stone can be generated by a sufficiently large flat Fresnel lens. This re-direction or focusing of this enormous amount of steady flux of energy does not require any supply of maintenance energy to the lens, yet we are re-directing enormous amounts of EM wave energy. Can we really re-directing and re-group energy without the use or leveraging assistance of any other source of energy? All propagation of light beams is accurately covered by the HF integral that has built-in secondary wavelets whose direction and location are dictated by the local phase conditions. Transmission gratings simply alter the phases of the incident wave front periodically. The direction of energy propagation is dictated by the phase matching of the secondary wavelets whose conditions are modified by the patterns on the gratings. No supply of external energy is required. How do the EM fields achieve re-direction of energy propagation by simply leveraging passive phase altering devices?

2. Material-based harmonic undulators and waves

Let us digress to appreciate the underlying situation by analyzing other forms of waves as water wave on a water surface or sound wave in atmospheric air. All material based harmonically undulating "stationary" objects or propagating waves require the existence of a tension force held under equilibrium. A clock pendulum undulates when an external force (energy) displaces it from its fixed equilibrium position due to the tension force provided by the

gravitational acceleration. In the absence of dissipative forces such undulations can continue forever. Planets are examples of one kind of “perpetual” harmonic undulation under gravitational tension. When a calm water surface is gently perturbed by an external energy source to displace the water surface from its stationary equilibrium position, one can observe propagating waves consisting of sinusoidally undulating surface amplitude. The tension energy behind water waves in small ponds is essentially due to surface tension produced by the attraction between water molecules that keep them as a compressible liquid with a well defined surface. Large amplitude ocean waves require deep water and assistance of gravitational tension. Unlike the case of the pendulum held on a fulcrum, the 2D water surface under uniform tension everywhere allows the local displacement to propagate away because every spot on the water surface wants to regain its stationary equilibrium state by pushing them away. That is why the propagation! Wherever the propagating wave group becomes manifest, it is leveraging the local surface tension energy. If a segment of the water surface is heated with a hot plate placed a short distance above the water surface to the steaming temperature, the propagating water waves will die out under the hot plate. Thus the tension energy under equilibrium is the key source for sustainable sinusoidal undulations.

When we talk or hit a tuning fork, we rapidly move an assembly of air molecules to compressed and rarified states. Normally, air is under the uniform pressure tension at equilibrium due to gravitational attraction on all of the air molecules, the pressure tension under equilibrium provides the energy for sound waves to propagate away. Except for various “frictional losses”, these propagating waves in water or in air, are not consuming the uniform tension energy. The state of tension energy existing over all space is simply leveraged to create the perpetually propagating wave packet. Once generated by the expense of some energy from an external agent, the wave forms simply keep on manifesting themselves as propagating waves by exploiting the available tension that is spatially continuous in every direction. When the waves pass through, the original local tension returns to the original equilibrium state as if no energy has been spent by the water surface-tension or the air pressure-tension. Note also that computational modeling of propagation (diffraction) of water and sound waves utilize a remarkably similar structure of diffraction integral like that of Eq.1. However, 1D wave on a string under tension would not diffract because of the 1D confinement of the sustaining string. Still the string wave propagation equation is quite instructive for us, especially if we can imagine that it is a very long one, unlike a guitar or a piano that generates only resonant eigenvalue frequencies due to reflective boundaries within a short distance. Infinitely extent water surface-tension, air-pressure-tension and a very long string-under-tension will be able to sustain any and all frequencies generated by a suitable technique and energy provided by an external agent within the physical limit enforced by the existing tension. No quantization needed for the allowed frequencies.

3. Cosmic Tension Field (CTF)

The successes of HFP driven integral in all field of wave propagations, whether the waves are material based or EM waves, and the need for the uniform tension energy for material waves, it is logical to hypothesize that EM waves must also be the undulation of some uniform tension energy field under the state of equilibrium that exists in all of cosmic space, including the spaces

occupied by entities that appear to us as material objects. Let us call it the Cosmic Tension Field (CTF). How is this hypothesis different from the “Ether Theory” of the 19th century? First, CTF is not a material-based medium like water molecules or air molecules. Second, we hypothesize that, unlike for water and air that are observable to us, CTF is only a pliable field without any “material-like” existence. We are not yet in a position to hypothesize as to exactly what gives rise to this uniform yet pliable CTF. This CTF has the intrinsic property of allowing the formation of EM waves whenever some form of dipole undulates in it, be they nuclear (x-ray), atomic (infrared to x-rays) or charge densities in antennas (radio waves). Thus, EM-waves are natural modes of vibration of the CTF (vacuum) but with space and time finite duration with sharply defined carrier frequency constrained by the requirement $\Delta E = h\nu$ for QM dipoles and the driving resonant frequency for the case of an LCR-circuit feeding the radio antenna.

CTF must have such a high tension value that even when material media embedded in it are excited non-linearly (non-linear optics, stimulus χE^n), the re-emitted energy as EM waves must first seek out the conditions for linear harmonic undulations and consequent emissions. This last assumption is strengthened by the observations that energy of exciting and non-linearly converted radiations follows the conservation laws. But, CTF hypothesis revives all the questions that were apparently solved by Relativity (space-time 4D universe, etc.). There is another question that stands out glaringly. How do material particles pass through this CTF without experience the “drag”? All these questions are also solvable with proper model for CTF and will be the subjects for a different series of papers [3, 4].

4. Removing wave-particle duality

We are now in a position to resolve the “wave-particle duality” issue for EM wave packets in favor of the classical model of divisible, diffract able EM waves just like wave packets in vast expanses of water surface, air or a very long stretch of string under tension.

Photoelectric effect does not require indivisible photon! The need for EM waves as indivisible packets of energy was incorrectly hypothesized by Einstein decades before formalisms for Quantum Mechanics was developed. We now know that most of the EM-wave-atom interactions can be formulated by semi-classical model where one uses quantized atoms stimulated as dipoles by classical EM waves [5-7]. Since electrons are indivisible particles and their binding energies are always quantized, photo-electric current will always consists of discrete numbers of electrons. Their rate of emission is determined by the arriving flux of light. Indivisible photons are not required to explain discreteness of photo electrons.

Quantum mechanical emission of a unique frequency does not require a Fourier monochromatic mode. Classical spectroscopic theory and measurements utilizing Fourier’s time-frequency theorem implied that if we have a time finite EM signal $a(t) = E(t)\exp(i2\pi\nu t)$ of temporal width δt , then it must contain a spectrum of distribution $\delta\nu$ that is given by the width of the Fourier intensity spectrum $|\tilde{a}(\nu)|^2$ where $FT[a(t)] = \tilde{a}(\nu)$. Experimentally, one does find that the spectral fringe intensity gets broadened by the convolution of the Fourier spectral density function $|\tilde{a}(\nu)|^2$. However, this fringe broadening can also be derived by direct time-domain

propagation of the carrier frequency ν and the amplitude envelope $E(t)$ of the wave packet through a classical spectrometer [2, 8] rather than the traditional approach of propagating the Fourier frequencies $\tilde{a}(\nu)$. This clearly implies that the fringe broadening is due to time-diffraction and spreading of the fringe energy correspond to the same original carrier frequency ν rather than accepting the non-causal assumption that a finite temporal duration of an EM wave necessarily means that it contains all the Fourier frequencies. The assumption is non-causal for three reasons. First, (i) well formed EM waves when superposed do not modify their energy distributions either in space or in time in the absence of interacting material dipoles [9-14]. Otherwise, fiber optic WDM communications systems would have been complete failures. Second, (ii) the generation of new optical frequencies also require the non-linear interaction (mediation) by material dipoles of suitable types with proper optical arrangement. Just insertion of a shutter in the beam for a brief moment does not generate new optical frequencies. This is one of the classic mistakes of classical physics that has been unwittingly carried into quantum mechanics. We believe that Dirac felt convinced that (i) Einstein photoelectric equation that correctly models measured data, must represent correct physics and that (ii) a space and time finite EM wave packet corresponds to a physical spectrum of width given by the time-frequency Fourier theorem. But highly successful QM demands that an atomic transition must give out a packet of EM energy $\Delta E = h\nu$, which must also have a uniquely defined frequency ν . Uniquely defined frequency in classical spectroscopy and coherence theory implies “monochromaticity”, meaning a light beam that has an infinite duration with a single carrier frequency. To keep both Einstein and Fourier happy, Dirac quantized the EM field such that a “photon” as a Fourier mode of the vacuum can simultaneously have a unique frequency ν and a total energy ΔE . But he sacrificed the causality. Because a space time and energy finite entities like atoms cannot but emit space time and energy finite entities. Dirac sacrificed space and time finiteness of atomic emissions by making it a Fourier monochromatic mode of the vacuum.

Doppler-free classical spectroscopy showed that there is a Lorentzian-like “natural” line width for emissions from of atomic discharge lamps. QM assumes that this is real physical distribution of emission frequency from an ensemble of excited atoms. However, the Fourier transform of a Lorentzian is an exponential function. Accordingly, we have hypothesized [15] that when atoms and molecules undergo a downward transition, they help generate a classical EM wave packet of carrier frequency exactly matching QM energy-frequency condition $\Delta E = h\nu$ and the temporal envelope of the wave packet is very close to an exponentially decaying pulse. However, this pulse, instead of starting from infinitely strong amplitude at $t=0$ (a pure exponential), we have proposed that it starts from zero, and then within a few cycle of ν , the amplitude rises to a finite peak and then decays down exponentially but reaching zero within a finite time. The shape of the temporal envelope is such that it contains the amount of energy ΔE . The proposed envelope being dominantly exponential, the Fourier transform will be Lorentzian, which is the observed spectral fringe broadening for “natural line width”.

5. Conclusion

We have presented logically self-consistent concept to do away with the wave-particle-duality for EM wave packets and pulses while stay congruent with the basic predictions of quantum mechanics. The amount of successes and new knowledge achieved through atom

quantization is staggeringly high and beyond any debate. In contrast, quantization of the EM field, instead of generating proportionately large amount of new information about the nature of light, it has helped impose enormous amount of unnecessary and non-causal constraints on the behavior of EM fields. This has slowed down the progress in exploring and understanding the deeper nature of light. We must try totally novel ways of looking at light consistent with observations and successful causal formulations. Our key proposal is the introduction of an all pervading Cosmic Tension Field (CFT) which is a natural extension of the Huygens-Fresnel principle. If we literally impose Reality Ontology on the Huygens-Fresnel diffraction integral, Eq.1, it requires a “source” of uniform tension field under equilibrium every where at every point. This is also true in our material world of water and sound wave propagation. So, introduction of CFT is not a conceptually radical proposition. The radical component would be how to accommodate “material particles” and their behavior through this all pervading CFT, which is our next ongoing endeavor [3] and looks quite promising while accommodating the successes of quantum mechanics

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