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Invited Paper

Are dark fringe locations devoid of energy of superposed fields?

Chandrasekhar Roychoudhuri

Photonics Lab., Physics Department, U. Connecticut, Storrs, CT 06269.

Catherine V. Seaver

Manchester Community College, Manchester, CT 06045

ABSTRACT

This paper speculates on the origin of dark energy & and dark matter as the potential energy of the cosmic medium as different forms of stresses in equilibrium. We are hypothesizing that EM waves and all particles are some form of undulations of different kinds of fields when the various stressed states of the cosmic medium are displaced from their equilibrium states. We have come to such conclusions as we have attempted to impose causality on the superposition effects we observe when EM beams or particles beams are superposed on detectors. We assume that detectors must experience all the incident beams on them simultaneously to be able to report the superposition effects; the fields themselves do not produce the energy re-distribution that we register as fringes. For light waves, this assumption is almost obvious because light or laser beams pass through each other without modifying each other. Yet, unlike bulk-matter waves, like those on water, we cannot "see" the fringes of light waves unless we insert detecting molecules within the volume of superposition. So, what undulates and how are the fringes are formed? We postulate that right kind of detectors with the right QM rules must do the summing of the influences brought on them by all the superposed fields simultaneously. We call this approach Reality Ontology (RO). We illustrate the concept with optical interference and diffraction experiments. Then we extend the "RO" concept to particle "interference" by hypothesizing that the relevant phases of the particles are due to some physical internal periodic undulations rather than de Broglie's "Pilot Waves".

Keywords: Interference of light, Interference of particles, Energy in dark fringes, de Broglie Pilot Waves, Dark energy, Dark matter.

1. INTRODUCTION

We would like to fore-warn the readers that this is a paper that attempts to extend a conceptual speculation beyond the traditionally accepted philosophy of quantum physics that superposition phenomenon is essentially non-local [1, 2]. However, first we will anchor our position that all observable superposition effects produced by superposition of light beams are necessarily local because we "see" light only through the "eyes" of the detectors and only when the microscopic molecules in our macro instruments are quantum mechanically (i) allowed to respond to the superposed fields, (ii) allowed to absorb energy and then (iii) produce some observable change in our instrument using the absorbed energy [3]. We are simply negating the possibility that microscopic molecules in our instrument can generate the macroscopically distributed superposition effects (fringes) without physically and simultaneously experiencing all the fields on them. Conceptually, we are imposing the "strong causality" which is if the fields are not directly interacting with the detecting molecules, they cannot produce the observed differential energy absorption pattern ("fringes"). We should not assign properties of the detecting particles to the superposed fields; otherwise we will be forced to assign un-physical behavior to the fields. Based on our current state of understanding, all interactions and energy exchanges in this world take place following the four force rules (electromagnetic, strong nuclear, weak nuclear and gravitational), all of which have finite ranges. In fact, the key theme of this paper is that dark fringes do not necessarily indicate the absence of field energy at that location. Spatial or temporal location of the "dark fringes" are simply the inability of the "local" detecting molecule to absorb energy from the superposed fields because the resultant stimulating effect is zero, not because of absence of field energy intercepted by the microscopic detecting molecules. What is the state of the energy in the "dark fringe" regions? If it is some form of

undetectable electromagnetic stress-field energy of the cosmic medium, could the concept be generalized to all other forms of stress-field energies that give rise to various superposition effects due to material particle fields? Further speculation on the origin of dark energy & and dark matter as the potential energy of the cosmic medium as different forms of stresses will be left to the imagination of the readers [4].

We will first elaborate our position regarding optical interference phenomenon using practical examples and underscore the presence of undetectable energy in the spatial and temporal domains. Then we will attempt to extend our concept of "real physical superposition" to the case of superposition of particle beams.

1.1 All waves propagate through each other unperturbed

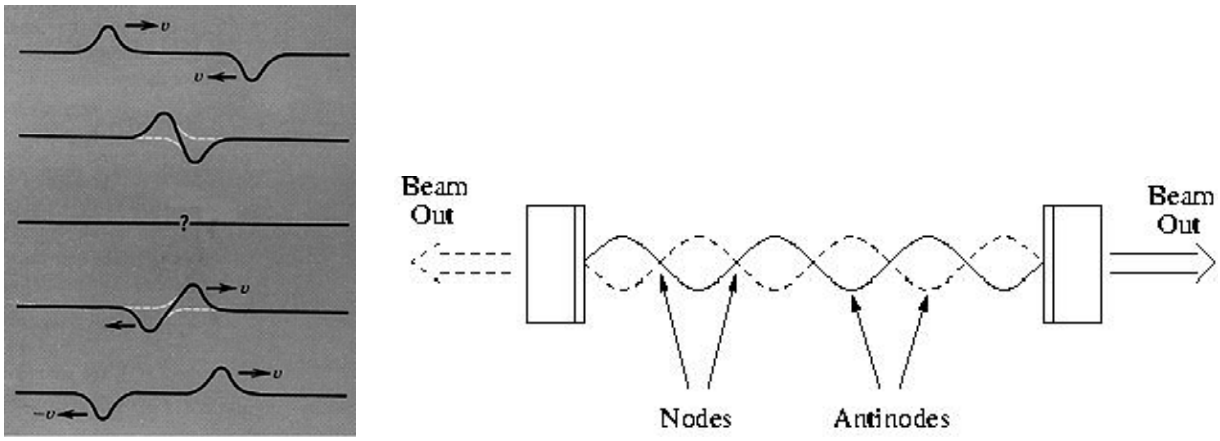
For centuries we have been taught that "interference" of light beams is occurring when we observe or record superposition fringes (spatial or temporal re-distribution of energy) during the superposition of two or more "coherent" light beams. In reality, well defined light beams or EM fields do not operate on (interfere with) each other to re-distribute their energies. Otherwise, the visual universe would be full of space and time scintillating speckle patterns. The measured Doppler frequency shifts of specific distant starts could not have been reproducible. The backbone of our global Internet system, based on WDM (wavelength domain multiplexing) technology that utilizes many signal carrying wavelengths through the same fiber, would have created time fluctuating noise, making the data belonging to the individual channels inseparable. Light does not produce the superposition effect in the absence of interacting material dipoles.

This absence of interaction between superposed EM-waves is not really new knowledge or unique. It is true of all wave phenomena. Water waves moving in different directions in oceans or lakes, generated by winds flowing in different directions, pass through each other unperturbed. Only in the physical domain of their overlap can we observe the modified undulations (fringes). This is because these water waves are undulations of the material medium water itself, unlike light waves which are undulations of electromagnetic fields in the invisible cosmic medium. Because of the very large inertial energy (mass) of water molecules, the water-wave-fringes can be easily observed by scattered light without appreciably perturbing them. The same logic applies to acoustic waves in air. The readers may recall how the sports telecasters use sound-telescopes to clearly pick up the comments by a referee from across the stadium, even though the referee's voice waves have to travel through thousands of other voice waves produced by the very noisy spectators! All well formed wave packets generated by a source propagate unperturbed through other similar waves in their respective media as long as the media are not nonlinearly distorted.

1.2 Light is a propagating undulation of electromagnetic stress field of the cosmic medium

When water and sound waves pass through each other unperturbed yet produce "bright and dark fringes" within the volume of their physical superposition, we explain the locations of the "dark fringes" (the absence of undulation of the medium) as transporting the "wave energy" as un-manifest local stress energy of the medium. Consider the simple example of two visible wave packets on a rope propagating in opposite directions with opposite phases. These waves are generated by quick hand undulations in the opposite directions by two experimenters while they hold the rope under some tension [Fig.1]. These undulations correspond to displacements generated at the two ends of the rope from their equilibrium positions. During the moment when they are exactly superposed on each other, the rope is completely devoid of any sign of physical undulations. But after very brief moment the two wave packets re-appear with their original phases and propagate out in their original directions, as if nothing happened when they passed through each other. The energy of the two wave packets were obviously still propagating through the rope but as an unobservable form of stress energy of the rope.

A somewhat analogous situation is encountered in a laser cavity bounded by two mirrors. A stable longitudinal mode (optical frequency ν) suitable for the lasing gain medium is chosen by the cavity of length L, such that $2L = m\lambda$, where m is the mode number or the number of antinodes of the "stationary wave pattern" contained by the cavity. Under a steady state condition, the light beams are continuously propagating in both the directions through each other. Yet, there are (m+1) nodes where optical activity is null because the cavity has opposing E-vectors in these locations where no stimulated emission is taking place. In contrast, the antinodes (Fig. 1b) experience the most intense stimulated emission activities and are named as regions of "spatial hole burning" [5]. Obviously, the EM field energies do not vanish at these nodal points, they became un-manifest like the waves on the rope.



(a) (b)

Figure 1. Superposed waves of opposite phase can become un-manifest at some physical space or time domain but the wave energy continues to propagate unperturbed even though the energy at these locations cannot be detected. The cartoon (a) shows rope waves of opposite phase passing through each other and becoming un-manifest for a moment during perfect superposition. The cartoon (b) shows the nodes and antinodes inside a laser cavity. At the nodes, with the oppositely moving field energies always out of phase, no stimulated emission action takes place. The antinodes are known as regions of "spatial hole burning" as the stimulated emission activity is strongest here due to the fields being in phase. [The sketch in (a) is copied from the book

Based on the observation that light waves, like water, air and rope waves, pass through each other unperturbed, could we hypothesize that the light wave packets are also some form of displacement produced in the cosmic medium that has a built-in electromagnetic field stress? Since the cosmic medium has eluded us from any direct observation of its presence and since optical fringes due to superposition of multiple fields in the same volume remain invisible until we put some material detectors within the volume of superposition, we could hypothesize that light waves are a form of displacement from equilibrium of the built-in electromagnetic stress field of the cosmic medium, rather than the undulation of the medium itself. Thus, light is really not a wave in the classical sense the way water, air and rope waves are. The latter are real undulations of the sustaining medium, whereas light is an undulation of the EM field, rather than the medium, which become manifest out of the electromagnetic stress potential energy of the cosmic medium. There has been a recent successful experiment which demonstrated that "vacuum" (cosmic medium) can be "polarized" by a strong magnetic field that can help generate measurable Faraday rotation of the plane of polarization of a light beam which is repeatedly bouncing within a super-finesse Fabry-Perot interferometer placed inside a super vacuum chamber [6].

If we revisit the evolution of electromagnetic theory and the development of all the later theories, one can observe that at every level of successful theorization of observed natural phenomena, nature repeatedly indicates that cosmic "vacuum" is not only not empty, it actually is a very rich medium giving birth to all possible observable fields, whether they have zero or finite effective inertial mass. Let us start with electromagnetism [7]. Experiments on electrostatics and magnetostatics forced us to assign ε_0 and μ_0 as the dielectric constant and magnetic permeability of the "vacuum", respectively. The rules of electromagnetism (Coulomb's, Ampere's, Faraday's rules and absence of free magnetic pole) evolved through the observations of the responses of materials to electric and magnetic fields dominantly through their dipole-like interactions with the electromagnetic fields. Maxwell's ingenious manipulation of these classical experimental rules of material response, along with the introduction of his "displacement current", yielded a wave equation indicating a propagating electromagnetic field with a velocity $\mathrm{v} = (\varepsilon\mu)^{-1/2}$ where ε and μ are the dielectric constant and the magnetic permeability of the medium, respectively. If the medium is free of any material dipoles, one can "obtain a material free" wave equation that indicates the velocity of light as $c = (\varepsilon_0\mu_0)^{-1/2}$. Thus, Maxwell's electromagnetic theory actually implies that the cosmic medium is a special case that is free of dipole-like material particles, and is not a real "vacuum".

It is worth noting that not all the predictions by even the most successful mathematical theories can be correct. The case in point is that Maxwell's wave equation accepts any linear superposition of its solutions. Yet, multiple superposed light waves propagate unperturbed though free space or transparent media without showing any manifestation of superposition effect. But, if the medium contains material particles that have QM properties allowing them to simultaneously respond to all the superposed fields, then only Maxwell's linear superposition becomes meaningful (operational).

1.3 Particles are quantized, localized, close-looped, vortex-like undulations of a different kind of stress field of the cosmic medium

The null results of Michelson-Morley (and similar experiments) have been interpreted as a proof of absence of ether as a medium required to sustain light waves. Without going into the debate [8] of the finality of M-M like experiments, we can fully appreciate the validity of the key assertions of Special Relativity. The constancy of the velocity of light in the cosmic medium is assured by $c = (\varepsilon_0 \mu_0)^{-1/2}$, in contrast to $v = (\varepsilon\mu)^{-1/2}$, when the cosmic medium is embedded with dipole-like material medium. This is very similar to the constancy of the velocity of water or air waves as long as the intrinsic stress properties of their respective media are not perturbed [cosmic Faraday]. When the embedded material medium moves with light propagating inside it, it is dragged and we know this through Fresnel's drag coefficient which had been experimentally validated before Relativity came along. When the source or the detector moves with a finite velocity within the cosmic medium, the detector registers a (Doppler) frequency shift only. Generation of multiple longitudinal modes (frequencies) by gaseous lasers (homogeneously broadened gain medium) due to random Maxwellian velocity distribution of the lasing atoms or molecules amply validates this concept. That is why a simple moving mirror introduces only phase shift on the reflected light beam, but not Doppler frequency shift [9, 10].

The key success of special relativity is that it assigned c as the highest possible velocity, $(\varepsilon_0 \mu_0)^{-1/2} > (\varepsilon\mu)^{-1/2}$. Therefore, there is no harm in hypothesizing that particles are quantized and closed-looped vortex-like [11] undulations of some "mass field stress" of the cosmic medium. The "mass field stress" of the cosmic medium is the potential energy whose displacement from the equilibrium produces the particles. This hypothesis, along with Einstein's proof that mass is not an immutable property of material particles, $m = E / c^2$, leads us to interpret that the property "mass" is derived as an inertial property of motion of the quantized vortex. It is now easy to imagine why the velocity of a stable vortex loop that has to move while keeping its identity intact, can never exceed that of the much simpler transverse undulation of the electromagnetic stress field. Note that we are assuming in both cases that the cosmic medium itself is not moving. They are the movement of the different types of stress fields generated by "plucking" the stressed medium from their equilibrium state.

General Relativity directly demands cosmic medium as something substantial because the cosmological "glue" comes out as a "curvature of space" [12]. And, the still evolving quantum mechanics is entirely based on "field equations", which has been forced to acknowledge "vacuum fluctuations" and "cosmic foams" [13] as possible realities. Accordingly, we propose that we should seriously consider cosmic space as the cosmic medium, and modify the quantum and gravitational field theories as real physical undulations of various fields of this cosmic medium, some of which are incessantly moving simple undulations and others are close-looped localized vortex undulations. The various stress fields in stable equilibrium are storing an enormous amount of potential energy in the cosmic medium, giving us some alternate possibilities regarding what may lie behind the "dark energy" and "dark matter" and why we experience barely 5% of the cosmic energy as manifest "mass".

1.4 We "see" light & superposition fringes through the "eyes" of the detectors

We do not see light unless some material atoms or molecules (dipoles) convert the energy of light into observable new signals. This also applies to the light sensing molecules, opsin, in our retina [14]. So, the response capability and characteristics of a light sensing molecule to the simultaneously superposed multiple light beams lie at the heart of registering superposition phenomena. It is the molecule, when allowed by its QM properties, that sums the superposition effects (sums the dipole undulations induced by all the fields) and undergoes the appropriate transitions, registering dark and bright fringes. When the sum of all the induced dipole amplitudes are in phase, many molecules can absorb energy from the superposed fields and register bright fringes. When the vectorial sum of the resultant field is null, the molecules cannot get stimulated and hence cannot absorb energy giving rise to what we call dark fringes. The dark fringes imply incapability of the molecules to absorb energy from the composite

fields; it does not imply absence of field energy at the sites of dark fringes. We call the imposition of such a physical process on the photoelectric equation behind detecting superposition effects *Reality Ontology* (RO) [3]

We cannot register fringes of superposition when the beams are orthogonally polarized even when they are coherent and are of same carrier frequency. This is not because orthogonally polarized light beams do not "interfere", but because the molecules (energy absorber or scatterer) can not undulate, being potential uni-axial dipoles, in two orthogonal directions simultaneously. Even in an isotropic medium they will respond to either one or the other EM field without being able to sum all the inducing effects due to the superposed beams. We cannot register the superposition effects due to two coherent light beams carrying different frequencies (as in Michelson or Mach-Zehnder interferometer), not because the beams are mutually "incoherent", but for the following reasons. (i) The same boundary layer dipoles of the interferometer beam splitter cannot respond to both temporally undulating fields at the same time to re-direct the field energies. (ii) The detecting molecules, like silver-halides in photographic emulsion, can respond destructively to the energy exchange process only once. They cannot keep on re-cycling with the resultant time-domain undulating E-vector to display the beat signal. And (iii) slow photo conductive detectors, in spite of their rapid recycling capability, cannot recycle themselves at the beat frequency due to inherent long-time-constant imposed by the built-in LCR values. Fast detectors with fast electronic circuitry can recycle themselves fast and do display beat signal. In fact, Forrester et all [15] realized the electronic limitations of ordinary detectors and demonstrated that even spontaneously emitted light of different carrier frequencies can generate detectable beat current at various different frequencies. Thus, the lack of observation capability of high visibility fringes (temporal or spatial) is not necessarily an indication of "incoherence" between the superposed light beams [16]. The measured "incoherency" is mostly the limiting property of the detectors including their effective integration time. It is worth noting here that that the atomic and molecular response time to photo induced reaction is in the domain femto seconds or shorter. But our fringe registration instruments usually have much longer integration time. The state-of-the-art streak cameras have about one pico second rise time.

It is the detectors inserted into the superposed volume that register superposition ("interference") fringes. Thus, all superposition fringes for light are "local effects" due to real physical interaction between the detectors (including beam splitters) and the superposed fields [3]. For material based waves, we "see" the undulations of the sustaining medium. For light, the sustaining cosmic medium has still remained invisible to us.

2. OPTICAL SUPERPOSITION FRINGES AS REAL PHYSICAL SUPERPOSITION OF MULTIPLE EM FIELDS

In this section we will first describe two classical two-beam interferometers. The first one is a Mach-Zehnder interferometer (MZ) with a few simple twists and real data to underscore that "which way" photons travel should not be considered as the decisive criterion to establish that "single photons" interfere. The second one is a Fresnel bi-prism experiment to underscore that dark fringes do not universally imply absence or non-arrival of photons. We have already previously underscored that the macroscopic dark-bright fringe distribution due to superposition of light beams becomes manifest only when the microscopic detector molecules can experience all the beams simultaneously on them so they can sum the effects of superposition. The energy of a single photon is so low that it is practically impossible to both track a single photon and allow it to "interfere". But we should not assign profound significance to this impossibility as the origin of strange (non-causal, non-local) quantum mechanical behavior of photons (and particles) in interferometers. Dark fringes are not necessarily the absence of arrival of photons at the dark fringe location. It is simply because the vector sum of the superposed E-fields is zero; the field energies pass through unabsorbed. Further, Panarella [17] has experimentally demonstrated that when the beam energy is literally reduced to the level of single photon propagation rate, one cannot produce fringes even with very long time exposure.

2.1 Can an indivisible single photon tackle a misaligned asymmetric MZ with orthogonally polarized light?

Our objective in this section is to demonstrate that every optical component in every optical path in an interferometer imposes its own unique characteristics of phase and polarization changes onto the light beams re-directed by them. The superposition effect is a summation of these accumulated shifts imposed on all the beams. Something must have the physical capability of carrying out this summation operation. Only proper detecting or scattering molecules can carry out this job of summation when their QM properties allow them to simultaneously respond to all the fields. EM fields by themselves cannot do the summation. But for the fringes to become manifest, the two beams carrying the uniquely modified properties from the two different interferometer paths must be

physically superposed on the detecting (scattering) molecules. It is a very causal and local process. We do not find it logically possible that just a reduction of the beam intensity to some arbitrarily low value can generate a new superposition phenomenon that violates causality and locality.

The MZ is shown in Fig.2a & b. It has two simple novelties. First, the source of light is a sealed-mirror He-Ne laser of cavity length 34cm. This laser emits a continuous wave (CW) that constitutes four longitudinal modes (frequencies spaced by 879 MHz) and its uniqueness is that the neighboring modes are always orthogonally polarized [18].

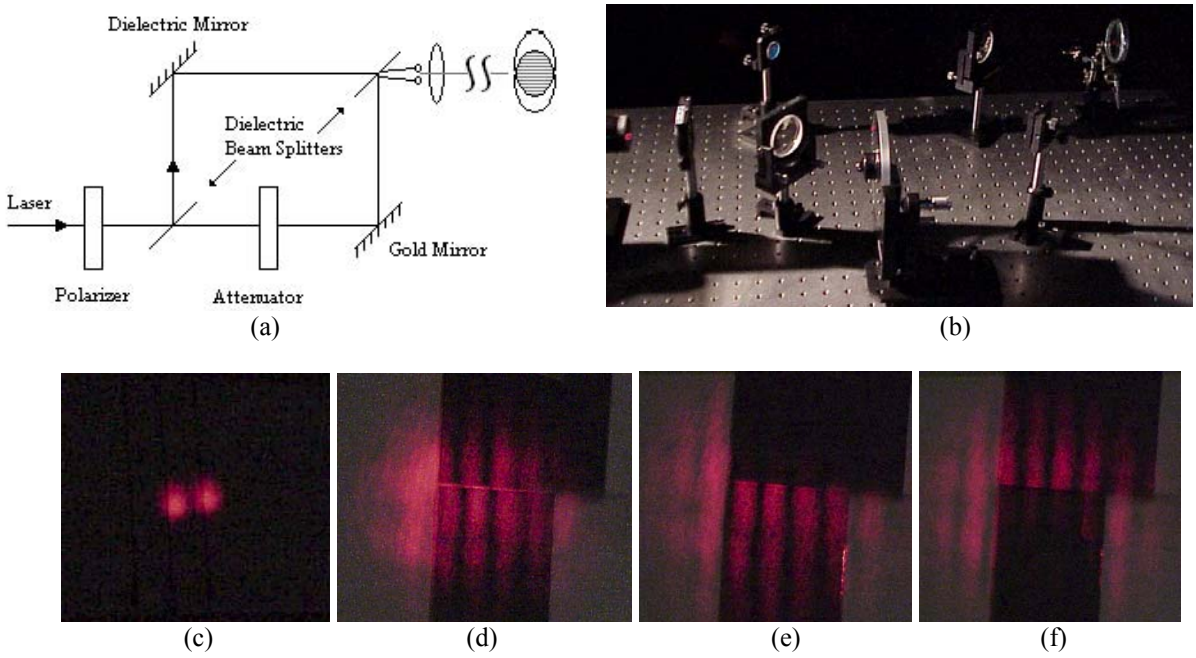


Figure 2. An asymmetric Mach-Zehnder interferometer with one metal mirror, one dielectric mirror and two dielectric beam splitters illuminated by a He-Ne laser emitting four longitudinal modes, alternate ones of which are orthogonally polarized as parallel and perpendicular to the plane of incidence to the MZ components. The asymmetry in mirror choice gives rise to a π phase shift between the two polarized beams and there is a π phase shift between the fringes produced by the two states of polarizations. (a) shows a schematic diagram of the MZ with a lens to manipulate the output beams physical size and superposition angle on an observing screen. (b) shows the photograph of the MZ. (c) shows the picture of the two beams on the screen without the lens in place indicating that the MZ produced beams are not collinear and coincident on the output beam splitter and hence beams are not producing interference fringes. When the lens is adjusted properly into the output beams to expand and physically superpose them on to the screen, even then one cannot see any fringes as is indicated on the left portion of the photo in (d) that is not covered by polaroids. The photos in (d), (e) and (f) are covered by two pieces of polaroids of which the top one is matched with parallel polarization and the bottom one is matched with perpendicular polarization. In the photo (d) one can see the fringes due to two orthogonal polarizations shifted. Unequal amplitudes of the orthogonal laser modes create unequal fringe contrast which prevents one from seeing exactly π phase shifts between the top and bottom set of fringes. However, this π shift becomes obvious if one compares the fringes in the two photos of (e) and (f). These two photos were taken, one at a time, by inserting perpendicular and parallel polarizers in front of the laser (before the MZ). This why the two polaroids on the screen separately appear dark in the two pictures.

We have mechanically aligned the tube to have its modes polarized parallel and perpendicular to the optical table. Second, one of the mirrors of the MZ introduces an asymmetry. Of the four key components, two mirrors and two beam splitters, the three components are dielectric and one mirror is metallic (Gold coated). Metal mirrors do not introduce any relative phase shift between the parallel and perpendicular polarizations in reflection, whereas the "external" reflections from all the dielectric surfaces do suffer a relative phase shift of π below Brewster angle [19, p.114]. Thus, while each of the pair of the output beams (parallel and perpendicular polarizations) experience identical physical path delays through the MZ, the perpendicular polarization picks up an extra phase shift of π compared to the arm that has the metal mirror. The MZ has been deliberately aligned to generate the two beams from the two arms coming out at an angle. The two 1 mm laser beams hit the screen on separate spots with no

physical superposition (Fig.2c). A lens after the MZ expands the beams and superposes them physically on a scattering screen (white paper). Still, one cannot see any fringes because they are washed out (left segment of Fig.2d); the two sets of orthogonal polarizations, due to an extra π phase shift, create fringes which are spatially out of phase washing out the fringe visibility to zero. But the fringes are visible (in Fig.2d), with spatial shift in position, behind two pieces of parallel (top) and perpendicular (bottom) polaroids taped on the screen. Fringes due to each polarization can also be seen separately (Fig.2e & f) if one blocks one or the other polarization before the beam enters the MZ.

Readers who believe in indivisible single photons and single photon interference are welcome to extend their imagination and reduce the light intensity entering the MZ to a single photon at a time. Then they must convince themselves how a single photon self-directs its arrival position on the screen by picking up a host of different information regarding (i) the differential phase shifts for the different MZ arms, (ii) whether the lens has been inserted to superpose the beams on the screen or not, and (iii) whether the two polaroids with orthogonal orientation have been taped on the screen or not. We believe that it is logically more self consistent to assume that photons are classical wave packets with a space and time finite amplitude envelope [3] which can be split into fractional wave packets by beam splitters and diffraction gratings just as classical physics have always assumed. When individual atoms or molecules emit a QM predicted packet of energy $\Delta E = h\nu$, we simply assume that the carrier (E-vector) frequency is ν, obviously a "plucked" mode of oscillation of the electromagnetic stress state of the cosmic medium, but within a space-finite volume, unlike an infinite Fourier mode.

2.2 Are dark fringe locations devoid of energy of superposed fields?

The purpose of this conceptually simple experiment is to re-emphasize that in the absence of a detector or scatterer, the superposed light beams cross through each other unperturbed. If one inserts a narrow slit at a location which would have been a dark fringe had a detector been placed in the same spot, the slit would produce two diffraction patterns corresponding to each of the two superposed beams on the slit as if the slit location was not a dark fringe [Fig.3]. One can register linear fringes parallel to the line bisecting the angle between the two propagating beams, but only within the volume defined by the amplitudes of the two space finite beams. Beyond the volume of superposition, the two beams are propagating out unperturbed by each other. Had the actual field energy distribution spatially changed as the fringes imply, then the two beams would have produced the so-called diffraction effects as if there were sinusoidal grating. Even an undeveloped linear photographic emulsion does not impose any diffractive effects [20]. Only insertion of photorefractive material can modify the propagation of the two beams because the medium immediately undergoes refractive index variation based on the energy absorbed by the constituent molecules.

Figure 3 shows a series of diagrams to convince the reader that this simple experiment can be carried out in any laboratory with a low power laser, a Fresnel bi-prism and a slit. By inserting a piece of paper within the volume of intersection of the two beams in Fig.3a, one can visualize the fringes of superposition because the scattering molecules of the paper where the E-fields are in opposite phase cannot stimulate the paper molecules to scatter out light. Can one register any light behind a narrow slit placed exactly behind one of the dark fringes? One would actually register two evolving and overlapping single slit diffraction patterns behind the slit. Of course, no obstructing screen should within the beams. This would be true until the slit size becomes much smaller than the wavelength of the light when the scattering by the two slit edges become cross-linked (superposed) due to extreme proximity of the edges.

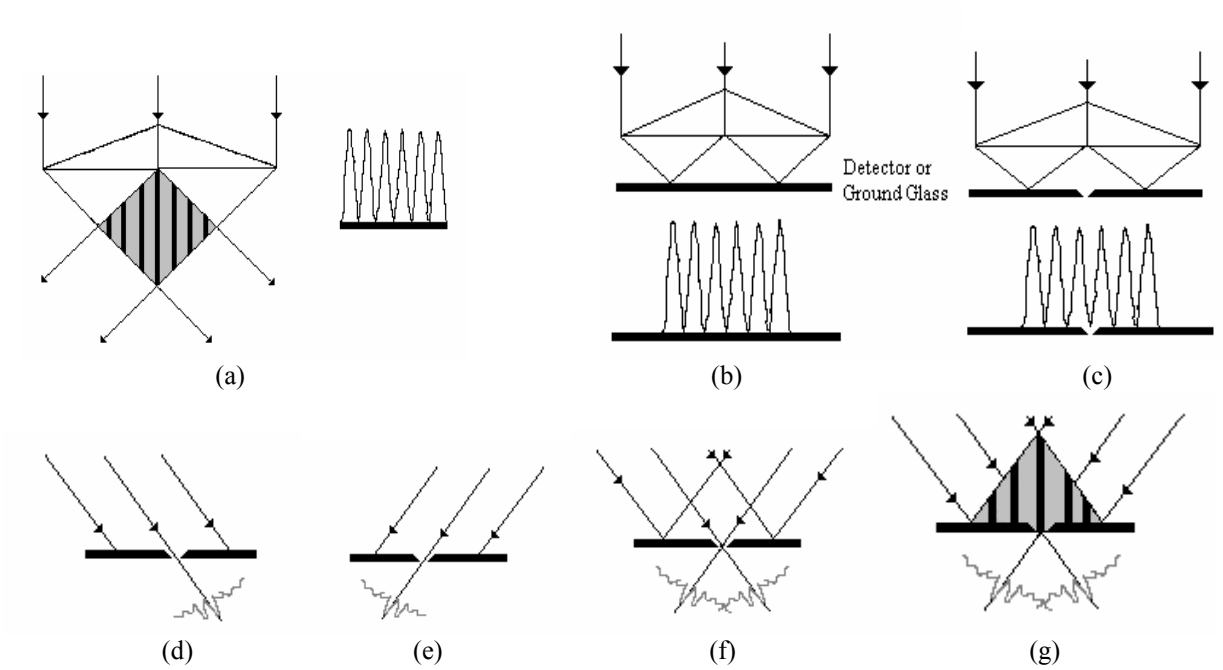


Figure 3. Virtual experiment with a Fresnel bi-prism to underscore that a dark fringe does not necessarily imply absence of light energy (or non-arrival photons). Two beams pass through each other un-perturbed as in (a). Insertion of a detector within the superposition space can give fringes, (b). A slit placed on the location of a dark fringe will produce two evolving diffraction patterns, (c) and (g). The diagrams (d), (e) and (f) are shown to convince the reader that (c) will produce (g).

3. PARTICLE SUPERPOSITION FRINGES AS REAL PHYSICAL SUPERPOSITION OF MULTIPLE PARTICLES

In this section we will be hypothesizing a novel concept to restore the causality and locality in particle superposition phenomenon. Our "success" in restoring causality in optical superposition phenomenon is based on i) light does not interact with light, ii) light amplitudes can be divided by diffraction gratings and beam splitters an indefinite number of times to arbitrarily low amplitude, and iii) detectors do the summation of the superposed fields to display superposition fringes. All classical and quantum mechanical experiments indicate that the first two points above used for light cannot be extended to particles. Particles are indivisible quanta. They interact with each and they normally do not pass through each other in regular "scattering" experiments. But we want to impose the third criterion, that it is the detector that does the summation process when it experiences multiple superposed stimulating particles

We have already hypothesized that neither EM energy packets nor particles are actually waves in the classical sense the way water, sound and rope waves are. For classical waves, a physical material medium sinusoidally undulates against its built-in restoring force and transports it with a characteristic velocity determined by the medium restoring force. EM energy packets are sinusoidal undulations of electromagnetic stress energy built into the cosmic medium. They are "wave" only in the sense that once generated, they have the characteristic velocity of $(\varepsilon_0\mu_0)^{-1/2}$ in the pure cosmic medium and $(\varepsilon\mu)^{-1/2}$ when the cosmic medium is embedded with material particles. For particles, we have hypothesized that they are also some kind of sinusoidal undulations (yet to be fully characterized) of a "material field", but they are localized, quantized and closed looped vortex-like undulation generated from the "material stress" potential energy of the cosmic medium. However, they are not the actual undulation of the cosmic medium itself. The movements and interactions of these quantized vortices follow the standard classical and quantum mechanics

We know that the superposition effects for particles are appropriately given by the QM phases formulated by the Schrödinger equation [21, p.164]:

$$\psi(x,t) = u_E(x)\exp(-i2\pi Et/h) \tag{1}$$

E is the kinetic energy of the non-relativistic particle in Eq.1. We will now attempt to connect the time dependent phase of a particle as dictated by the second term of Eq.1 with its internal properties. Let us step back into the basic properties of optical fields given by $\nu\lambda = c$. We know from experience that the frequency is a fundamental physical characteristic of light, the frequency of undulations of the E-vector. We also know that λ is the physical distance (varying from material to material) that light travels during one complete undulation period ($1/\nu$) of its E-vector. The time varying phase that a detector experiences when interacting with light beam is given by:

$$E_{EM}(t) = a(t)\exp(-i2\pi\nu t - i\phi_0) \tag{2}$$

Our point is that an internal frequency of undulation may be a more plausible for a discrete particle to possess than a "wavelength"; and yet it provides the required sinusoidal phase undulation required for "amplitude superposition". Further, de Broglie wavelength $\lambda_{dB} = h/p = h/m\mathrm{v}$ becomes indeterminate when the particle velocity approaches zero at extremely low effective temperatures. So, let us hypothesize a novel internal frequency of undulation ν_L for particles that does not become indeterminate:

$$\nu_L = \alpha\nu_0 + \beta\nu_{dB} + \gamma\nu_{nl};\ \text{ where } \nu_{dB} = \mathrm{v}/\lambda_{dB} \tag{3}$$

The de Broglie frequency ν_{dB} is the inverse of the time the particle takes to traverse a distance λ_{dB} while finishing one complete internal undulation period. This is congruent with the phase factor produced by the de Broglie "wavelength relation", yet it does away with the need to seek for some physical wavelength associated with particles and the concomitant wave-particle duality. Energy exchange between coupled pendulums is guided by the superposition of their harmonic amplitudes and yet they are not waves. They do not need "wavelengths" to manifest superposition effects, but they do have the necessary periodic phase undulation through their inherent frequency of oscillations. Similarly, we assume that all particles, including elementary particles, atoms and molecules, are little quantized "pendulums" with some periodic internal undulations. In Eq.3 α, β and γ are yet to be determined. ν_0 is the internal undulation period when the mean velocity of the particle is zero and $\gamma\nu_{nl}$ is the contribution under nonlinear conditions like relativistic velocities and/or when the cosmic medium itself becomes highly distorted due to the presence of other fields. Using the standard definition of non-relativistic kinetic energy, $E = p^2/2m$, de Broglie wavelength, $\lambda_{dB} = h/p = h/m\mathrm{v}$, and the de Broglie frequency, $\nu_{dB} = \mathrm{v}/\lambda_{dB}$, as we have defined, one can obtain:

$$E = (1/2)h\nu_{dB} \tag{4}$$

This is without any other internal QM energy level excitations. Equations 1 and 4 now give us the necessary legitimacy of the velocity dependent time evolving phase of particles in QM. The advantage of this novel undulation hypothesis is that we now have a physically accountable phase (not wavelength) for particle-particle interaction, built into Schrödinger's equation, which can accommodate phase-driven superposition effects without the need of introducing any mysterious "pilot wave" associated with particles in QM philosophy.

However, we now have a serious conceptual problem in explaining superposition effects due to particles. Unlike EM waves, individual particles are not divisible and cannot diffract as a classical coherent wave front. Therefore, the only possible way to explain the phase driven superposition effect generated by detectors is to assume that a detecting particle must have a finite time of interaction to get stimulated before any quantum transition takes place, which is also automatically built into the QM recipe for observables as $\psi^*\psi$ [3]. During this very short interaction period, if two exciting particles with opposite phases (of internal undulations) are superposed on a detector particle, the detector particle can not be stimulated just as it happens when two EM undulations of opposite phases cannot stimulate a photo detecting molecule. What does this mean to fringe quality in particle-particle superposition experiments? Since most particles arrive with enough energy to be detected by the detecting particles, the "bright fringe" peaks will have relatively more "clicks" than the dark fringe minima. For dark fringe minima to remain 'zero' after a prolonged exposure, the stimulating particles must always arrive in even numbers with opposite phases to keep the detector particle from registering them at all. This is statistically almost impossible. In other words, our

hypothesis implies that the minima in a two-slit particle diffraction experiment can never remain perfectly zero even with the best possible experimental attempts. So, we are copying the classic two-slit neutron diffraction pattern by Zeilinger et. al. [22] in Fig.4. The visibility of the cosine fringes,

$$\mathbb{V} = (I_{\max} - I_{\min})/(I_{\max} + I_{\min}) \tag{5}$$

instead of being unity, it is steeply degrading with the angle starting from the center to the edge. Even at the center the visibility is only 0.6, far bellow unity. In the middle (3rd fringe from the center), the visibility is between 0.27 and 0.32. It is practically zero at larger angles even where the accumulated count is close to 300. Our hypothesis of real physical undulatory phase carried by particles and built into Schrödinger's equation explains the arrival of neutrons everywhere as simple scattering by the slits. Simultaneous arrival of these scattered neutrons with pairs of in-phase and out-of-phase neutrons on the detector superimposes two-beam cosine fringes.

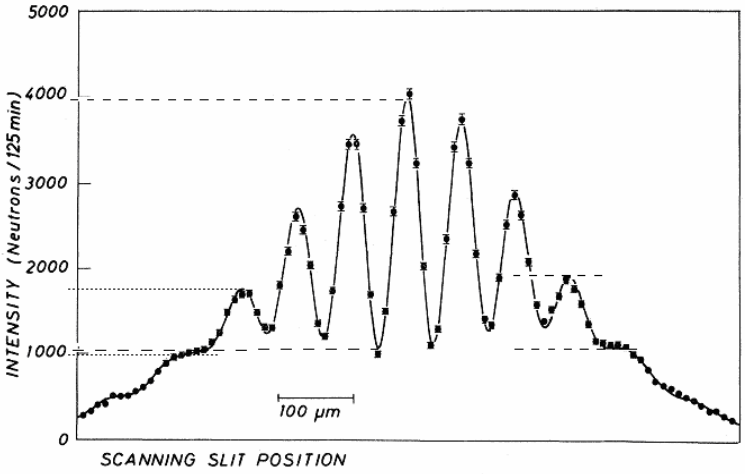


Figure 4. A classic double slit neutron diffraction pattern by Zeilinger et al [22]. Note that the visibility of the fringes even at the center of the pattern is barely 0.6 which indicates the detection (arrival of) a large number of neutrons at the null regions. We explain this as arrival of some random single neutrons besides simultaneous arrival of even number of neutrons with opposite phases. The phase we hypothesize is due to some actual internal sinusoidal undulations of the particles that dictate interactions capability with the detectors. The "opposite phases" required to generate the null fringes is not due to de Broglie "Pilot Waves".

We must caution the reader that our proposed heuristic hypothesis (internal particle undulation) still needs a lot of work before it can be claimed as a competing alternative to de Broglie hypothesis. In this context, we would like to quote Zeilinger's cautionary words, "…we suggest that any proposals for alternative theories should be checked in great detail against our experimental evidence" [22]. Zeilinger has been a pioneer in superposition experiments and his group is still producing phenomenally high quality work for both light and particle superposition experiments [23, 24, 25]. Accordingly, the readers are fore-warned that this section of the paper is highly speculative at this stage. Further development will be presented later.

4. SUMMARY & DISCUSSIONS

We have proposed that causality in superposition phenomenon can be restored if we combine (i) the semi-classical model of light as divisible classical waves and detectors as quantum devices [1b], and (ii) the hypothesis that it is the detectors that carry out the summation of superposed fields. To bring operational congruency between different superposition effects of light (superposition of orthogonally polarized and different frequency light, etc.), we had to hypothesize that light is some form of undulation of a field (electromagnetic) generated by the "plucking" actions of the undulating atoms or molecules on the electromagnetic stressed state of the cosmic medium, which otherwise remains dormant as un-manifest electromagnetic potential energy in equilibrium. Then, we have extended similar concept to particles and hypothesized them as quantized closed-looped vortex-like undulations of another kind of field generated out of the same cosmic medium. This field is generated by a different kind of "plucking" action out of a different kind of dormant stressed state of the same cosmic medium in equilibrium. We call this stored energy as "mass-stress energy" of the cosmic medium. We use the word "mass" because the inertia of motion experienced by this vortex like field generates what we experience as the traditional inertial mass of the particles. Then we have hypothesized that the phase of some form of internal undulation of frequency ν_L of these particles is the same phase

as has been formulated by Schrödinger's equation. Equating that frequency with the inverse of the time period necessary to travel the de Broglie distance λ_{dB} distance, we have derived the particle's kinetic energy, without any internal quantum excitation as $E = (1/2)h\nu_{dB}$. This undulation, rather than de Broglie "Pilot Wave", is the cause behind sinusoidal phase variations of particles. When two similar particles with opposite phases are simultaneously superposed on a detector particle, it cannot get stimulated and cannot register their presence, giving rise to a "dark fringe". The process is very much like that for two light beams arriving with opposite phases on a photo detector. However, for the case of indivisible particles, the probability is always finite for the arrival of isolated particles that can trigger detections individually irrespective of their absolute phases. The imposition of this concept of real physical superposition of multiple particles with their variable phases on a detector to produce the superposition effect implies strong statistical reduction of visibility of two-slit particle diffraction patterns. We have argued in favor of the validity of this assertion by referring to the low visibility neutron diffraction fringes from Zeilinger's paper.

In the process of developing self congruent hypotheses to bring causality and reality [26] to superposition phenomena for light and particles, we had to hypothesize that the cosmic medium possesses various forms of potential stress energies that are capable of giving rise to different kinds of undulatory fields which we experience as mass-less light and particles with inertial mass. Thus, the cosmic medium appears to be an enormous reservoir of various kinds of potential energies. We can then further hypothesize that the stability of this stressful cosmic medium requires that not all of its potential energies become manifest as electromagnetic fields and particles. Is that why current cosmology cannot account for more than 5% of the manifest energy [4] in the universe? Can some portions of yet undetermined "dark energy" and "dark matter" be accounted for by the potential stress energies of the cosmic medium that we have hypothesized?

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