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Why do we need to continue such a conference? To re-vitalize classical and quantum optics

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Abstract

The origin of this conference series has started with the publication of a special issue, “The nature of light: What is a photon?” by Optics and Photonics News, OSA, October, 2003. This issue contained five articles by well-known main stream people from several countries. In 2005, SPIE allowed us to organizing an out-of-box conference series on the same topic; and we have just completed the 3rde biannual conference with great success and enthusiastic participations by many thinkers. Many of these participants believe that all successful theories must be periodically re-evaluated from its base to modify and correct, as necessary, based on newer and more advanced information. This particular article establishes the assertion of the last sentence by identifying paradoxes and contradictions existing in current text books on classical and quantum optics. We show that these can be resolved simply by explicitly adopting the well known reality that propagating waves in the linear domain do not interact by themselves. This Non-Interaction of Waves (NIW), or the NIW-principle also helps us to appreciate that time-frequency Fourier theorem should not be used as a physical principle of nature because waves of different frequencies, by themselves, cannot interact to create new time-domain pulses. Further, Fourier “monochromatic components (modes)”, existing in all space and all time, do not represent any reality as they violate the principle of conservation of energy. Consequent impacts in classical and quantum optics are summarized in this paper, which should help the readers to appreciate the vital importance as to why we should continue such an out-of-box conference with steadily increasing vigor.

Keywords: Non-Interaction of Waves (NIW); Non-Interference of Light (NIL); Superposition effect; Measurement epistemology; Locality of all measured transformations; Non-reality of infinite monochromatic waves; Non-reality of Fourier monochromatic frequencies; Light is always coherent; Incompleteness of all theories.

1. INTRODUCTION

We consider that a deeper understanding of the nature of light, beyond that of the current level, would give rise to new break-through fundamental progress in physics. Electromagnetic radiation (energy), from very low frequency Radio waves to the highest frequency Gamma rays, whether propagating from across the entire cosmic system or across our laboratory bench, bring to us characteristic information about the material universe from where they originated, whether macro bodies or molecules or atoms or nucleus or elementary particles. We would have lost a significant amount of our information gathering capabilities about the material universe had these EM radiations modified each others key intrinsic characteristics, frequency and polarization, while propagating through each other; or, had they interfered with each other. There are no forces of interaction between EM radiations. No other material particles can help us gather unadulterated information about their source since they alter their original characteristics while they scatter from each other. There is always some force of interaction between material particles depending upon their mutual distance. Only neutrino appears to have somewhat similar characteristics like EM radiation, but their controlled generation and detection are still quite difficult and elusive. The author believes that a comprehensive foundational studies about generation, propagation and detection (light-matter interactions) of EM waves across the entire spectrum should be carried out anew, while “riding on the shoulders of the giants” who have already contributed enormous amount of knowledge over the past several centuries. Historically optics has been one of the most important enabler for developing of both pure physics and technologies. Further, no other type of probing energy to explore a natural object has as much flexibility as light (EM) waves have. This talk will raise conceptual questions from several branches of current physics that explain the fundamental nature of light with built-in contradictions and paradoxes. This article is a brief summary of ideas published by the author as “out-of-box” concepts over several decades [1-41]. The author is also further emboldened by recent critical publications by several renowned authors like Smolin [42], Laughlin [43], Penrose [44] and Woit [45] with questions and suggestions about the direction of physics research. Current “successful” theories are clearly resistant to smooth unification. So we propose a new strategy of re-visiting the very foundations of all the “successful” theories and reconstruct them from bottom up by introducing new hypotheses to modify or replace old ones where recent measurements or conceptual revisions encourage us to do so.

As a modest attempt, we show that the principle of non-interaction of waves (NIW) is a fundamental property of all waves including EM waves, which has been missed by classical physics and co-opted by quantum physics, in spite of their realization that photons are non-interacting Bosons. Light beams can be forced to co-propagate through highly constrained medium (as in nano photonics waveguides) and yet emerge without loosing any of their fundamental characteristics. Neglect of the NIW principle has caused the invention and introduction of a number of unnecessary and non-causal concepts into physics. In fact, Dirac came closest to realizing the NIW principle, and yet negated his realization, perhaps in reverence to centuries of successful classical physics, and declared: “Each photon then interferes with itself. Interference between two different photons never occurs” [46]. In well behaved and an orderly evolving universe, self interference of stable elementary particle is a non-causal proposition. By simply applying the NIW principle [10], we show that one can significantly enhance the conceptual explanations of most optical phenomena (light-matter interactions) without the need of non-causal concept like ‘single photon interference’, ‘teleportation’, ‘creation of multiple universes during every quantum mechanical transition’, etc. Hopefully, some of the successful examples of revision of classical physics, presented in this paper, will become an inspiring guide to embark on more ambitious projects of revising other branches of physics by the next generation.

This paper has been organized as follows. We summarize a number of contradictions and paradoxes from current physical optics in Section-2. Section-3 presents a methodology of thinking as to how one should go about gathering information about the interactants under study through measurements. This *Measurement Epistemology* [34] tells us that we can only measure transformations experienced by interactants under the guidance of one of the four allowed forces, which implies all measurements (interactions) are *local* and we will always be “information deprived”. Since there is no photon-photon interaction force, light beams do not interfere. And, strict use of conservation of energy implies that all light signals must be space and time finite, which makes theories built out of using or propagating infinitely existing “monochromatic wave” susceptible to mistakes, if one fails to recognize that Fourier’s “monochromatic waves” can neither “interfere” nor can exist in reality. Section-4 summarizes the consequences of these limitations in current classical and quantum optics, which need to be revisited.

2. CONTRADCITIONS & PARADOXES

Let us first list a few contradictory or paradoxical assumptions behind current “understanding” of optical phenomena.

Spectrometry. In classical spectrometry, we consider the spectral fringe width derived by using a CW (infinitely long) “monochromatic” (single carrier frequency) plane wave as instrumental width that must be de-convolved to derive the correct result. This width is not the real physical spectrum. However, if the light, to be spectrally analyzed, is a time-finite pulse, we immediately assume the “spectrum” is the Fourier transform of the mathematically imagined envelope function of the pulse, irrespective of whether the pulse contained a single or multiple carrier (E-vector undulation) frequencies. Interestingly, we tacitly assume that a “transform limited” pulse contain only a single carrier frequency under a finite envelope function; that is how we always present the pictorial model for a pulse.

Coherence. For “interference of light” (coherence theory), more than a century ago, Michelson hypothesized that different optical frequencies do not interfere. All modern Fourier Transform Spectrometry (FTS) assume this algorithm; and it works! However, since 1955 [47], after the discovery of very fast photoelectric detectors for the visible range, we have established the theory and technology for Light Beating Spectrometry (LBS), where different optical frequencies do “interfere”! We measure the normalized degree of coherence (autocorrelation function), $\gamma(\tau)$ through visibility of fringes [48]. Our formulation recognizes that replicated and delayed superposition of pulses, $a(t)$ and $a(t-\tau)$ with unequal amplitudes produce time varying fringe visibility even when the pulse contains a single carrier frequency, $a(t)\exp[i2\pi\nu_0 t]$. And yet, we assign the time integrated reduced visibility as due to the Fourier “spectrum”, $\tilde{A}(f)$ where $a(t)\Leftrightarrow\tilde{a}(f)$ form a FT pair and $\tilde{A}(f)=\left|a(f)\right|^2$. We leverage the theorem of Wiener-Khintchine (WK) which says that the autocorrelation function and the Fourier spectral intensity function form a Fourier transform pair, $\gamma(\tau)\Leftrightarrow\tilde{A}(f)$ (assume $\tilde{A}(f)$ is normalized). Mathematically savvy reader may note that the Fourier conjugate variable for WK theorem is ((f,τ) , whereas, those for the original Fourier transform for the pulse is (f,t). Note that t is the running time and τ is experimentally introduced relative delay; and f is the mathematical Fourier frequency and ν_0 is the actual E-vector undulation frequency. In deriving WK theorem, we switch between t and τ based on mathematical conveniences with complete disregard to what are physical realities.

Polarizations. In two-beam interferometry, if the two superposed beams, produced from the same source, are converted to orthogonally polarized states, the fringe visibility goes to zero. Logical argument is that orthogonally polarized light beams cannot produce any superposition effect. And yet, we assume that when we superpose the same two orthogonally polarized light beams with exactly 90^0 relative phase delay, we produce a single beam with elliptically polarized, spiraling E-vector!

Mode locking. As mentioned above in the "spectrometry" section, FTS require non-interference of different frequencies, in contrast to LBS. Does mode locking follow LBS principle, instead of FTS? What is the difference? Highly coherent laser beams from different lasers easily give steady light beating heterodyne signals. However, in WDM, even though we force many highly coherent laser frequencies, amplitude modulated with data, to co-propagate through thousands of kilometers of hair-thin fiber. They never "interfere" to produce irrecoverable noisy beat signals. WDM works beautifully!

Divisible vs. indivisible photon. That EM waves, at all frequencies, propagate always diffractively and spread accordingly, being inversely proportional to the frequency, is well established. This is true whether the propagation takes place in free space or through simple or complex diffractive apertures. It is also well established that when EM waves are generated or absorbed by "quantum cup" like, molecular, atomic or nuclear entities. The exchange of energy happens in discrete packets, $\Delta E_{mn} = h\nu_{mn}$. However, the propagation of photons is not dictated by the "quantum cups" except near the vicinities of emission or absorption by suitable dipoles. Photon energies are divisible, even though, many quantum optics people believe that diffraction phenomenon is only a scattering phenomenon. What induces "scattering" on a collimated TEM_{00} Gaussian laser beam as it expands over a square mile are as it arrives on the moon, which is precisely accountable using Huygens-Fresnel diffraction theory?

While inverse proportionality of diffractive divergence [49] to frequency allows gamma photons to preserve their strong particle-like nature, their divisibility is obvious from their tracks in volume-scintillation detectors as they keep on loosing their energy in a series of discrete interactions. The divisibility of X-ray photons is obvious from the classic Compton scattering where every scattering from an electron, the original photon gives up a part of its energy and comes out as a lower frequency photon. The divisibility of visible photons [50] is obvious from nonlinear optical processes like parametric down conversion [51]. Summability of visible photons is obvious from nonlinear frequency summing and two-photon fluorescence processes. Of course, QED also claims that the original photon in all interaction processes is first absorbed completely and then a new indivisible photon is emitted. Physicists must accept a common conceptual premise so debates can produce productive and logical outcomes.

3. MEASUREMENT EPISTEMOLOGY

Development and validation of theories in physics critically depend upon how we extract information from our measurements. Accordingly, it is vitally important for us to dissect the measurement process and how we gather information about nature. We need to develop a methodology of thinking about measurements or develop a *Measurement Epistemology*. We have sub-divided the *Measurement Epistemology* into three distinct steps: (i) Locality, (ii) Incompleteness and (iii) Non-Interaction of Light (NIW).

3.1. Measurement Epistemology-1; Locality:

We logically establish that no real physical experiment, in contrast to *Gedanken or Thought Experiments*, can establish that measurable transformations in nature can be non-local [Fig.1]. This is because our experiments measure some transformation in our chosen interactants that must exchange some energy allowed by some real force of interaction with entities in our detector. Since all forces have a finite range, the interactants must be "local" to within each others range of influence. Since interaction-free transformation cannot occur in nature, we cannot claim non-locality in any experiments of physics. In other words, all transformations are necessarily "local superposition effects (LSE)".

3.2. Measurement Epistemology-2; Incompleteness:

Next we establish *Incomplete Information Paradigm (IIP)*. We can never gather complete information regarding any physical entity through any single experiment because of its inherent limitations in gathering information from (or about) the interactants both at the input and the output end of the experiment. Logical arguments behind this assertion are provided ion Fig.2 and the figure caption. In other words, all sensors, comprising of the interactants and the transformation measuring device, wear “vision-limited goggles” and report through “band-limited” communication channel [21]!

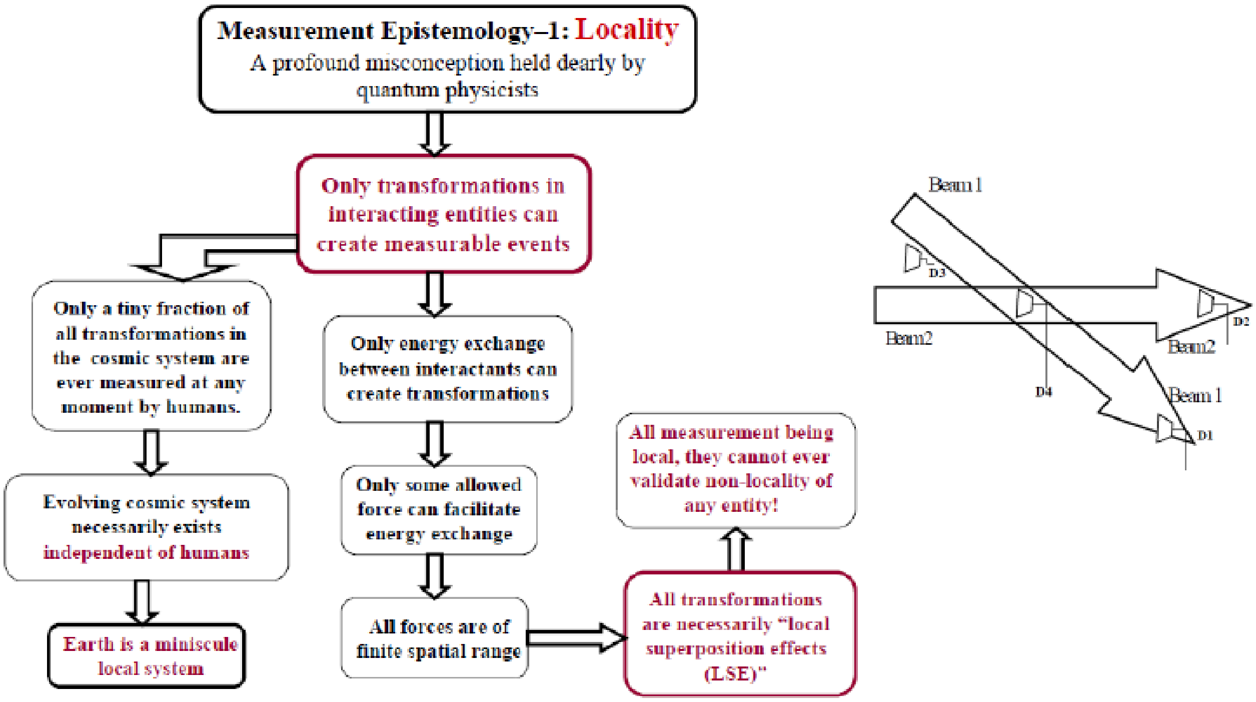

Figure 1. The chart on the left provides a logical flow to establish that all superposition effects are necessarily “local” because the interactants must be within each others sphere of influence to produce any measurable transformations. On the right, we establish the need for “locality” in optical interference by showing that only the detector D4 can register any superposition effects since collimated and narrow laser beams are physically superposed on it. D1, D2 & D3 cannot give us any information regarding whether the two laser beams physically superposed anywhere in space.

We can appreciate this Incompleteness Information Paradigm (IIP), by considering the superposition effects on a detector of a laser beam consisting of two longitudinal modes or frequencies of equal amplitudes using a traditional Michelson’s two-beam interferometer. If we use a very fast detector at the output, it will receive four components, two pairs of delayed beams for each frequency, as shown in Eq.1. The resultant photo current will have a constant, two τ-dependent “DC” terms and four t-dependent terms. If this current is analyzed, for a given fixed value of τ, by a high speed electronic spectrometer analyzer (ESA), it will ignore the DC current and will display a sharp line at the beat frequency $\delta\nu = (\nu_2 - \nu_1)$. This is a form of light beating spectroscopy (LBS). Note that, even though there is no longer any explicit dependence on the running time t, the analysis of $D(\tau)$ depends upon the integration time of the ESA following the fast detector. For short times on the order of seconds, the phases of the modes of a He-Ne laser are reasonably constant and Eq.1 remains valid. But, if one sets the integration time of the ESA to much longer time, the ESA signal will be noisy due to phase fluctuations. However, when the light detector itself has a very large intrinsic LCR-time constant, or a photographic plate (as Michelson did), one can register fringes only by varying the interferometer path delay τ, as shown in Eq.2. This is how Michelson discovered his Fourier transform spectroscopy (FTS), because the Fourier transform of the cosine terms (neglecting the constant), tells us the presence of two frequencies. Note that in Eq.2, unlike in Eq. 1, the square modulus of the four terms has been split up into two sets of square modulus terms under the assumption that different frequencies do not interfere (cross terms must be zero). This is because a very slow detector suppresses (time averages) the heterodyne beat frequency in the detector current. Michelson received *incomplete information* from his slow detector (photographic plate) and wrongly assumed that different frequencies are incoherent! Even today FTS is carried out by deliberately using very slow photo detectors. Deeper understanding of physics comes from awareness that there are many hidden information that we are missing or suppressing depending upon limitations of our measuring instruments that tries to record light-matter interaction processes. We can construct a “correct theory”, as in Eq.2, and have a very successful experimental tool, FTS, but under a wrong physical assumption that different optical frequencies are "incoherent"! It is the signal integration time-constant of the photo detector and that of the follow-on analyzer, which determine the characteristics of the registered fringes.

$$D(\tau) = \left| e^{i2\pi\nu_1 t} + e^{i2\pi\nu_2 t} + e^{i2\pi\nu_1(t+\tau)} + e^{i2\pi\nu_2(t+\tau)} \right|^2$$

$$= 4 + 2[\cos 2\pi\nu_1\tau + \cos 2\pi\nu_2\tau] \quad (1)$$

$$+2\cos 2\pi(\nu_1 - \nu_2)t + 2\cos 2\pi\{(\nu_1 - \nu_2)(t+\tau)\} + 2\cos 2\pi\{(\nu_1 - \nu_2)t + \nu_1\tau\} + 2\cos 2\pi\{(\nu_1 - \nu_2)t - \nu_2\tau\}$$

$$D(\tau) = \left| e^{i2\pi\nu_1 t} + e^{i2\pi\nu_2 t} + e^{i2\pi\nu_1(t+\tau)} + e^{i2\pi\nu_2(t+\tau)} \right|^2 = \left| e^{i2\pi\nu_1 t} + e^{i2\pi\nu_1(t+\tau)} \right|^2 + \left| e^{i2\pi\nu_2 t} + e^{i2\pi\nu_2(t+\tau)} \right|^2$$
$$= 4 + 2(\cos 2\pi\nu_1\tau + \cos 2\pi\nu_2\tau) \quad (2)$$

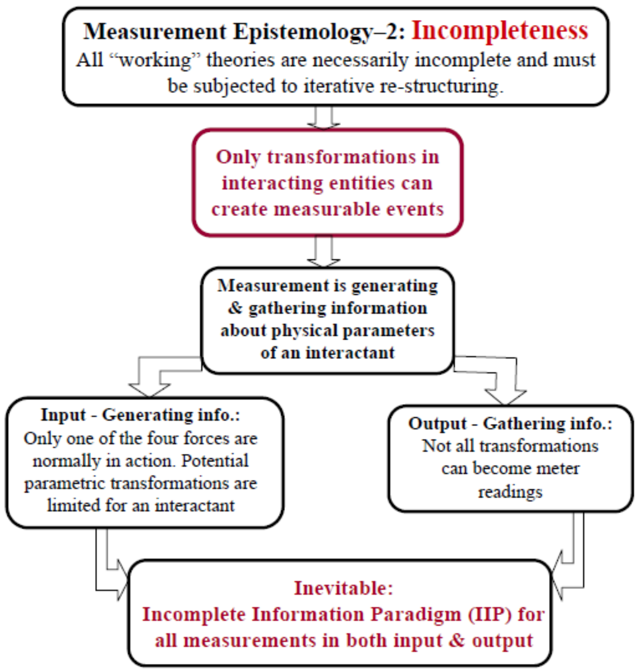

Figure 2. This flow chart establishes the universality of Incomplete Information Paradigm (IIP) in all experiments since some of the information, both in the input and the output side of the experiments, will always be missing. In the input side, only a limited set of physical parameters of the entity under study can come into play since we usually set up the experiment to study only one of the known four forces. In the output side, detecting system usually is incapable of transmitting (or transferring) all the information related to the transformations that have occurred inside the apparatus. Thus, we are forced to fill in the missing information with conjectures, or hypotheses created out of human logics, which may appear to be logically congruent for a finite set of experiments, while failing to capture the universal cosmic logics.

Missing information, filled in by human hypotheses, are never above mistakes as they are derived based on incomplete knowledge of the universe! This is why we have proposed that all theories (organized bodies of human knowledge) are necessarily incomplete, since they have been organized based on insufficient knowledge of the universe. In other words, declaration that some theory is final and complete implies that we are ready to stop our mental evolution as far as that particular field of knowledge is concerned. The Buddhist epistemology is an excellent guide to overcome this limitation. Analyze sensorial input information like blind men. Collaborate and compare similar "hypothesis" with many to synthesize knowledge by bringing conceptual continuity among diverse information while enforcing logical congruence among them. And still the newly organized knowledge will be incomplete since information gathered were a small segment out of the entire universe! We must always keep on correcting & refining "old" knowledge retroactively and iteratively. We will succeed in visualizing the invisible processes going on in nature only when we are mentally liberated enough to accept that in reality we are all "blind". We send the sensorial inputs to our brains. It is the brain that dictates us, for its survival convenience, what we should 'see', 'smell', 'taste' or 'think'! Recall that photons are not ‘colored’, neither the molecules have ‘taste’ or ‘smell’. These attributes have been invented by the programs in our neural networks to facilitate our evolution. They are not truly objective information, even though we may all agree about these attributes and even figure out how to quantify them!

3.3. Measurement Epistemology-3; Non-Interference of Light (NIL):

We have been carrying a major conceptual mistake in physics for centuries for lack of developing any measurement epistemology. It is the principle of non-interference of light (NIL). Light beams always pass through each other unperturbed in their beam energy distributions unless they are intercepted by some interacting material dipoles. Then the stimulated dipole, whether energy absorber or scatterer, responds to the joint stimulation, or sum the all the stimulation effects, and absorb or scatter energy based on the square modulus of the sum of the superposed complex amplitudes. So the superposition effects (fringes) are always a manifestation of simultaneous response of material dipoles to all the superposed electromagnetic fields. It is an active interaction effect, not a passive “interference” phenomenon. It is the polarizability of material dipoles, and the consequent quantum transitions that help us “see” light! Detectors or scatterers must create the measurable transformations for the “fringes” to become manifest. If light waves “interfered” by themselves, then the visual world would have been full of spatial and temporal scintillations (speckles). WDM internet data, passing through many kilometers of hair-thin glass fiber, would have been destroyed by temporal beats (heterodyne effect). The expanding universe, indicated by Doppler shift, would not have been measurable, since the beam from any particular star has to cross through innumerable other star beams.

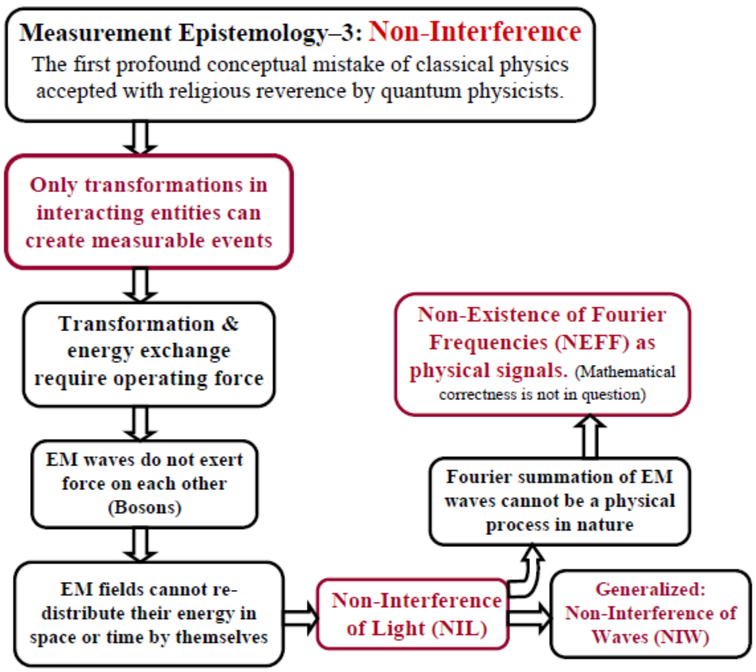

Figure 3. Optical fringes due to superposition of multiple light beams become manifest through some measurable transformations induced by light-matter interaction. In the absence of some material within the volume of superposition, light beams pass through each other unperturbed. There is no “interference” of light beams.

A deeper understanding of our classical wave theories will guide us to correct our quantum & all the various “successful” field theories. Logical flow of the measurement epistemology is shown in Fig.3

The following mathematically correct linear superposition relations, Eq. 3a & 3b, do not represent any real physical *interaction process* in optics. Acceptance of linear superposition of harmonic waves by Maxwell’s wave equation implies only that many waves can co-propagate through the same cosmic space. Maxwell’s equation does not necessarily imply that they interact with each other to form a new resultant wave with new energy distributions. Energy redistribution always requires some interaction with some mediating material that can experience the electromagnetic force and exchange energy. There is no force of interaction in play between electromagnetic waves themselves. All registered superposition phenomenon between light beams become manifests through some measurable transformation experienced by a detector.

$$\text{Maxwell: } \nabla^2 \overline{E} = (1/c^2)\partial^2 \overline{E} \big/ \partial t^2 ; \quad b_{total}(t) = \sum\nolimits_n b_n \exp[-i2\pi\nu_n t] \tag{3a}$$

$$\text{Fourier: } a(t) = \int_0^\infty \tilde{a}(f)\exp[-i2\pi ft]df ; \;\; \tilde{a}(f) = \int_0^\infty a(t)\exp[i2\pi ft]dt \tag{3b}$$

If we imply by the summation signs of Eq.3 as interactions, then we must model an interactant that can carry out the summation. We must convert the E-vectors into undulating dipole vectors by multiplying it with the detecting molecules' polarizability factor ${}^{(1)}\chi$. Then we have a proper superposition relation [21] as shown in Eq.4a & b. The dipoles sum all the simultaneous stimulations induced by light both in the linear and the non-linear domains. However, for the sake of simplicity, we have used only the linear susceptibility to polarization by EM field:

$$\text{Maxwell: } \quad d_{total}(t) = \sum\nolimits_n b_n\, {}^{(1)}\chi(\nu_n)\exp[-i2\pi\nu_n t] = {}^{(1)}\chi \sum\nolimits_n b_n \exp[-i2\pi\nu_n t] \tag{4a}$$

$$\text{Fourier: } \quad a(t) = \int_0^\infty {}^{(1)}\chi \tilde{a}(f)\exp[-i2\pi ft]df \; = {}^{(1)}\chi \int_0^\infty \tilde{a}(f)\exp[-i2\pi ft]df \tag{4b}$$

Notice that when ${}^{(1)}\chi$ is a constant for a given material for a given range of optical frequencies, one can take ${}^{(1)}\chi$ out of the "summation" or the "integral" sign as a "common factor" as per mathematical rule. Then the RHS of Eq.4a & b look identical to those in Eq.3a & b. This "correct" mathematical rule has "fooled" us from realizing what carries out the real summation (interaction) implied by the *Superposition Principle*! Physics cannot have a "principle" without identifying a proper force behind the "interaction process" that creates measurable transformations. The terms b_n or $a(t)$ represent non-interacting EM fields which operationally should not be summed. Whereas, ${}^{(1)}\chi b_n$ and ${}^{(1)}\chi a(t)$ represent a component of the dipole undulation induced by one of the incident E-vectors. When allowed by the intrinsic properties, these dipole undulations facilitate the resultant energy exchange as square modulus of the sum of all the stimulations. Unfortunately, we have been making a major conceptual mistake for centuries by thinking that ${}^{(1)}\chi$ is just a "detector constant" representing its intrinsic properties, as if it has nothing to do with the summation of the EM fields.

If light beams do not sum themselves, obviously, time-frequency Fourier theorem, albeit its mathematical correctness, does not represent real physical behavior of light beams. One must be careful how to use this theorem without getting into pitfalls in the real world. Further, Fourier frequencies being infinitely long "monochromatic wave", it is a non-causal non-physical solution for optical phenomenon, discussed further in the next section.

3.4. Measurement Epistemology–4; Conservation of Energy: & Non-Existence of "Monochromatic" Waves (NEMW):

The second profound conceptual mistake of classical physics is its assumption that "monochromatic" wave of infinite existence can be used to model light propagation through practical (real world) instruments without incurring any fundamental mistake. This has also been accepted by the founders of quantum physicists with complete religious reverence with the consequence, as the author believes, that the Copenhagen Interpretation outsmarts mysticism by invoking "non-locality", "force-free" or "interaction-free" measurable transformations, appearance of "multiple universes" in every quantum mechanical experiments carried out human beings! A Fourier harmonic monochromatic plane wave mode, $\psi(t) = a\exp[i2\pi\nu t]$ by definition, extends to all time and all space! The total energy content is infinite:

$$\text{Total Energy } = \int_{-\infty}^{+\infty} \left|\psi(t)\right|^2 dt = \int_{-\infty}^{+\infty} \left|ae^{i2\pi\nu t}\right|^2 dt \le \infty \;\text{ only when } a = 0. \tag{5}$$

Smart mathematical manipulation to restore divergences cannot correct the fundamental conceptual mistaken hypothesis that one takes as the starting platform. It only forces us to introduce one after another ad hoc hypothesis and interpretations to make sense out of observed phenomenon. Conservation of energy dictates that all real entities and waves must be of finite extent and finite energy, which led Newton to surmise that light must be "corpuscular". Unfortunately, it was way too early for him to fully appreciate that those "corpuscles" also do not "interfere" by themselves. Nineteenth century physicists, taking the cue from Fourier's successful theorem, that any finite signal can be expressed as a summation of an appropriate series of infinite sinusoids, have developed theories to propagate a pulse by propagating the Fourier frequencies of the mathematical envelope that can be imagined to contain the finite EM radiation. Everybody "assumed" for centuries that light beams interfere by themselves, which was further "validated" by the fact that Maxwell's wave equation accepts any linear superposition of "monochromatic waves", which does not exist in reality. The lesson is that elegant and working mathematical equations are not necessarily "God's Equations". They are just tools, albeit the best tools so far, to help excavate nature's orderly, logical and causal interaction processes. When a tool turns out to be of no further use, or gets blunt, it is time to invent new tools, fundamentally new logics and new mathematics. Our physics is now mature enough that we should feel confident enough to inspire new Newtons to discover totally new "differential algebras", instead of thwarting our evolution by enforcing on everybody that "working theories" constitute the complete unchangeable final theories!

4. IMAPCT OF NON-INTERACTION OF WAVES (NIW) IN PHYSICS

In the last section, we have shown that when we develop a logically systematic methodology of thinking as to how we gather information through various experiments combined with "common sense" conservation of energy, we are forced to accept the following regarding all measured transformations. (i) ***Locality:*** All interactions are always "local" and force assisted interactions. (ii) ***Incomplete Information Paradigm (IIP):*** We can never gather all the relevant information from a single experiment. (iii) ***Non-Interaction of Waves (NIW):*** Emitted photons (light) propagate as diffractively spreading waves (inversely proportional to its frequency) through each other without interfering or modifying each other energy distribution [49]. (iv) ***Non-Existence of "Monochromatic" Waves (NEMW)****:* When one combines NIW-phenomenon with conservation of energy, we can easily appreciate that monochromatic waves, existing over all times, cannot exist. Further, time-frequency Fourier theorem, reliant on physical interference between light beams, cannot help us consistently model propagation of light pulses by propagating "monochromatic" Fourier frequencies through dispersive media where each Fourier frequency has a different physical velocity. Yet, the time-frequency Fourier theorem "works" in all branches of physics. We have established through a series of papers, where and under what limited conditions, the celebrated theorem works, and where it fails, when we observe carefully [4,11,12,28]. The logical flow-chart is shown in Fig.4.

4.1. IMPACTS IN CLASSICAL PHYSICS.

In the limited space of this paper, we will stay focused in giving the summary of impacts of NIW (together with NEMW) in the next few paragraphs. The impacts in mathematics and quantum physics will be discussed elsewhere.

4.1.1. Spectrometry: The resolution limit $\delta\nu\delta t \geq 1$ is not a principle of nature. This issue has been discussed in several earlier papers [11,12,21,22]. We will give here the summary observations. All spectrometers function as a finite (N) beam (or, pulse) replicator with the insertion of a periodic time delay τ. Spectral fringe width in all classical spectrometers depends upon the effective number of physically superposed beams. For gratings, N represents the number of effective slits intercepted by the lateral size of the beam. For a Fabry-Perot, N represents the effective finesse number. Thus, a spectrometer generates a train of N partially superposed pulses extending over a period $\tau_0 = N\tau$ with mutual separation of τ. Thus all spectrometers have an intrinsic time constant $\tau_0 = N\tau$, which classical physics has missed out by propagating the Fourier "monochromatic" components of a pulse. By propagating the carrier frequency ν of a pulse $a(t)\exp[i2\pi\nu t]$ of finite duration, instead of its Fourier frequencies $\tilde{a}(f)$, one can directly calculate the time varying intensity from Eq.6 verifiable with a Streak Camera [current technology limits us to analyze pulses with duration longer than multiple pico seconds]. In free space, this will be correctly predicted by Fourier approach also. However, if one records this time-varying "spectral" fringe with a photographic plate, or a camera with a time constant much longer than τ_0, the width will be given by Eq.7. We call this as the pulse-response function, because it does not contain any optical frequencies. This is wider than that due to a very long (CW) pulse, because of partial superposition of the replicated pulses. When the incident pulse is much longer than the intrinsic time constant τ_0, then all the replicated pulses are effectively superposed on each other. Under this limiting condition, Eq.7 reverts to the classical "CW" formula, as shown in Eq.9. For shorter pulse, the time-integrated fringe width can be mathematically shown to be equivalent to the convolution of the spectrometer CW response function with the Fourier intensity function $|\tilde{a}(f)|^2 = \tilde{A}(f)$, while replacing ν by f, and by using Parseval's theorem of energy conservation.

Time varying intensity: $$|i_{out}(t)|^2 = \left|\sum_{n=0}^{N-1}(1/N)a(t-n\tau)\cdot\exp[i2\pi\nu(t-n\tau)]\right|^2 \qquad (6)$$

$$\text{Time integrated intensity: } I_{pls}(\nu,\tau) = \frac{1}{N} + \frac{2}{N^2}\sum_{p=1}^{N-1}(N-p)\gamma(p\tau)\cos[2\pi p\nu\tau] \tag{7}$$

$$\text{Autocorrelation function: } \gamma(p\tau) = \int d(t-n\tau)d(t-m\tau)\; dt \Big/ \int d^2(t)\; dt \tag{8}$$

$$\underset{\delta t\to\tau_0=N\tau}{Lt.}\; I_{pls}(\nu,\tau) = \frac{1}{N} + \frac{2}{N^2}\sum_{p=1}^{N-1}(N-p)\cos[2\pi p\nu\tau] \equiv \frac{1}{N^2}\frac{\sin^2 \pi N\nu\tau}{\sin^2 \pi\nu\tau} \equiv I_{cw}(\nu,\tau) \tag{9}$$

$$I_{pls}(f,\tau) \approx \int_{-\infty}^{\infty} \left| i_{out}(t) \right|^2 dt = I_{cw}(f) \otimes \tilde{A}(f) \tag{10}$$

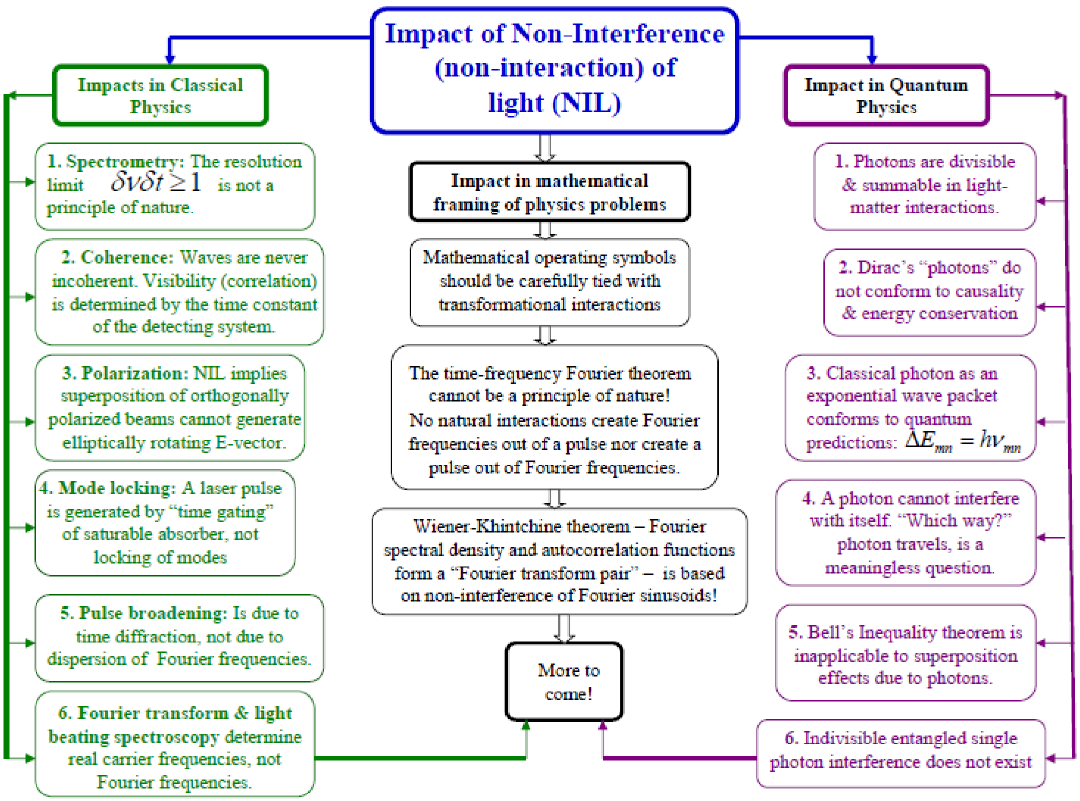

Figure 4. This chart gives a summary glimpse of diverse impacts of non-interference of light (NIL) in physics, divided into three segments, (a) classical physics, (b) mathematical physics and (c) quantum physics. See text for further details.

Note that we have recovered the classical CW spectral fringe formula [Eq.9] in the limit when the pulse width exceeds spectrometer time constant τ_0. We have also recovered the classical assumption that the spectral fringe width due to a pulse is the convolution of the Fourier spectral intensity with the CW response function [Eq.10]. Perhaps, it is because of this coincidence, as shown in Eq.10, that classical physics failed to appreciate NIL-principle, and took time-frequency Fourier theorem as representing the physical reality. Obviously, directly propagating the carrier frequency of a pulse gives us a deeper understanding of the physical processes behind spectral analysis.

Since the Eq.7 represents the pulse impulse response function, obviously the apparent fringe width $\delta\nu$ does not represent the presence of any new optical frequencies. Accordingly, $\delta\nu\delta t \geq 1$ does not represent any fundamental principle of nature. If one has a pulse $a(t)$ that may contain more than one carrier frequencies, Eq.7 will be further broadened due to the summation over all these carrier frequencies. However, one can still recover the real spread of frequencies by de-convolving Eq.7 (for single carrier frequency) from the measured fringe function. Of course, a separate measurement of $a(t)$ by a fast detector, or by autocorrelation method, will have to be carried out first.

4.1.2. Coherence: Waves are never incoherent. Visibility (measured correlation) is determined by the time constant of the detecting system [16, 35]. Let us first acknowledge that we measure visibility of fringes, which we then mathematically equate to "coherence" or the normalized autocorrelation function. We routinely generate white light fringes with interferometers and diffrcatometers with high visibility (correlation) where the order of interference $m = \Delta / \lambda \approx 0$; at higher orders, the fringes tend to wash out slowly. So, light cannot be intrinsically "incoherent" to each other! It is the measurement conditions that dictate the fringe visibility. One might argue that it is really the "coherence" length of light that is important. In reality, it is the integration time of the detector that dictates the visibility of fringes. Consider the superposition of a pair of pulses separated by one half-width, whether nano second or femto second long, passing through a streak camera screen... If the camera "shutter" remains open for the entire duration of propagation of the pulse pair, the fringe visibility will be very poor. However, if my camera is capable of opening its shutter only during the brief moment where the amplitudes of the two superposed pulses are almost equal, I will register very high visibility fringes. Has the intrinsic "coherence characteristics" or the "intrinsic spectral characteristics" of the original pulse changed between these two registrations that only differ by duration of exposure? Intrinsic properties of the partially superposed light pulses have remained unaltered. They are not "incoherent" or "partially coherent".

Besides, we must also acknowledge that light beams do not interfere or interact and hence field-field correlation is not a directly measurable quantity. We measure the transformation experienced by the stimulated material dipole $\vec{d}$ of the visibility measuring detector; the strength of which is determined by the resultant E-vector, $\vec{d} = \sum_n {}^{(1)}\chi \vec{a}_n$. Our confusion comes from the fact that the *normalized* autocorrelation function for the dipole stimulation due two fields appears identical to that of the fields only, because we apply the mathematical rule of cancelling the identical terms ${}^{(1)}\chi^2$ from the numerator and the denominator, which deprives us from understanding the deeper physics behind the light-matter interaction processes:

$$\gamma_t(\tau) = \frac{\left\langle {}^{(1)}\chi^* a_1^*(t)\, {}^{(1)}\chi a_2(t-\tau) \right\rangle}{\left\langle \left| {}^{(1)}\chi^* a_1(t) \right|^2 \right\rangle^{1/2} \left\langle \left| {}^{(1)}\chi a_2(t-\tau) \right|^2 \right\rangle^{1/2}} = \left\langle a_1^*(t) a_2(t-\tau) \right\rangle \Big/ \sqrt{I_1}\sqrt{I_2} \qquad (11)$$

We propose that optical coherence theory should be re-defined in terms of measurable fringe visibility based on the physical parameters of light that actually quantitatively modify the visibility. (a) *Temporal Visibility* $\gamma_t(\tau)$, which is dictated by superposition of unequal amplitudes as obvious from the Fig.5. (b) *Spectral Visibility* $\tilde{\gamma}_\nu(\tau)$ due to the presence of real multiple carrier frequencies in the light pulse. In a slow detector, the fringes due to each frequency are displaced at the m-th order by $m_q = \nu_q \tau$ for the same path delay τ causing degradation in fringe visibility. This is at the root of algorithm used by Fourier transform spectrometers. (c) *Spatial visibility* due to spatially distributed sources with random phases. This is modeled well by the van Cittert-Zernike theorem [48] and need not be elaborated any further. (d) *Complex visibility* that can be produced due to various possible mixture of the above three visibility conditions.

4.1.3. Polarization: NIW implies superposition of orthogonally polarized beams with 90^0-phase shift should not generate an elliptically rotating E-vector [33]. The standard text book derivation for the equation of an elliptically rotating E-vector is actually carried out by eliminating the time variable! Optical beams co-propagate through the same space unperturbed by each others presence. In fact, this is obvious from the way we analyze the propagation of polarized light. We always decompose an arbitrary state of polarization into a pair of appropriate pair of orthogonal x- and the y-components. The x- and the y-component sets are propagated separately to find the final set of orthogonal components. Total energy is always the sum of the separate square modulus of the x- and y-component sets; they do not interact with each other. So, we cannot create a helically spinning E-vector by superposing two orthogonally polarized beams with 90^0 relative phase shift between them. For a polarizer, we take the projections of the two amplitudes along the polarizer axis and then sum and take square modulus to get the total energy. So, a polarizer can be considered as a "single component" interferometer when two polarized beams are sent through them simultaneously [33].

We have carried out very careful fringe visibility measurement using a Mach-Zehnder interferometer with two rotatable polarizers in its two arms [33] to demonstrate that E-vectors do not form a new resultant vector before interacting with detectors!

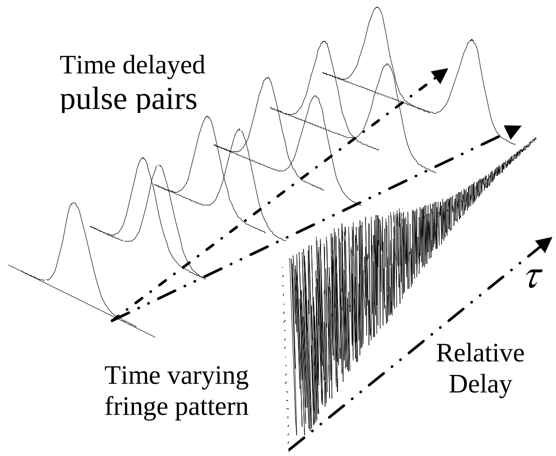

Figure 5. Temporal visibility degradation due to superposition of unequal amplitudes [from ref.16].

4.1.4. Mode locking: A laser pulse is generated by "time gating" of saturable absorber, not locking of modes [20,24,36]. Pulse generation from laser cavities is always a *time-gating phenomenon* due to light-matter interaction with the intra-cavity saturable absorber, Kerr medium, etc. It is not a *mode locking phenomenon,* because the photons of the light beams corresponding to the modes of a laser cavity do not interact (interfere) with each other to re-group their energies within a shorter space and time. Most short pulse generating "mode locked" lasers use homogeneously broadened gain media with very broad gain bandwidth, which always tend to run in a single frequency at the gain line center that has the highest gain under CW condition. Can a passive intra-cavity saturable absorber or a Kerr medium switch the spectral characteristics of a homogeneously broadened gain medium into an in-homogeneously broadened gain medium to make the laser run in multiple longitudinal modes? We believe that, under controlled and stable conditions, the lasing medium runs in a single mode (frequency) at the center of the gain medium and the intra-cavity saturable absorber or the Kerr medium simply plays the role of fast time gating (switching). This implies that "transform limited" "mode-locked" laser pulses, in reality, contain only a single carrier frequency. The reader may look back at the Eq.7 & 10. Eq.7 shows the time integrated (classical) spectral fringe width due to a pulse with a single carrier frequency. Eq.10 then defines the characteristics of a "transform limited" pulse with a single carrier frequency. The necessity of very broad gain bandwidth to derive very short pulse does not come from the availability of a very large number of longitudinal modes from the gain medium, which is not true for homogeneous medium anyway. Very broad gain bandwidth provides very fast storage capability of pump energy and very fast extractability of the energy through stimulated emission since all lasing centers are equally accessible for both pump and stimulated emission processes.

4.1.5. Pulse broadening: Is due to time diffraction, not due to dispersion of Fourier frequencies [11,25,28]. We have established in the Section 4.1.4 on spectroscopy that a direct propagation of the carrier frequency through a spectrometer gives us a much better and deeper understanding of the physical processes by which spectral fringes are formed. We then also derived the classical formulations as a special case whenever the pulse is much longer than τ_0. We also identified that a grating produces N pulses with step delay τ creating a new composite pulse of duration around $\tau_0 = N\tau$. This is diffractive pulse stretching or broadening.

Besides, we have experimentally demonstrated that simple superposition of light of different frequencies does not synthesize into a new pulsed light beam with a new mean frequency, as Fourier theorem, claims [10]. In another heterodyne experiment [22], we have demonstrated that pulses chopped out from a single mode CW laser, do not contain Fourier frequencies (FT of the temporal envelope). So, for the propagation of a pure pulse containing single carrier frequency, we should propagate the envelope function with the carrier frequency using the Huygens-Fresnel (or Rayleigh-Sommerfeld) diffraction integral without substituting Fourier frequencies of the envelope [40]. To appreciate our point, we have computed a couple of counter examples [11,25] where we propagated the periodic array of Fourier frequencies due to a periodic array of input pulses and showed that one can obtain the original (un-broadened) pulse after propagating the pulse train through a specific long length of a single mode fiber. Obviously, this is impossible! Intuitively one can appreciate that when the incident frequencies are periodic, one can always choose a desired length of a fiber for a given dispersion curve, such that all the frequencies will suffer modulo-2π phase delays and be in phase again at the output as they were in the input.

4.1.6. Fourier transform & light beating spectroscopy, FTS & LBS determine real carrier frequencies, not Fourier frequencies. In Section-3.2 we have actually presented Eq.1 & 2 to illustrate the issue *Incomplete Information Paradigm (IIP).* There we presented the logic that a slow detector, like a photographic plate, robbed the beat frequency information, which made Michelson to declare different optical frequencies are incoherent and hence they do not interfere. Of course, they do not interfere, but they are not "incoherent" either, which has been discussed earlier. Here we just note that ν_1 and ν_2 in Eq.2, representing the total recorded fringe function, are actual carrier frequencies of the input signal. One can neglect the "DC" term in Eq.2, as Michelson did, and then carry out "Fourier transformation" of the variable fringe function $(\cos 2\pi\nu_1\tau + \cos 2\pi\nu_2\tau)$, and extract the values of ν_1 and ν_2. This is FTS. Eq.1 helps us carry out LBS as difference signal $\delta\nu = \nu_1 - \nu_2$. Absolute determination of any one of the frequencies will still require separate spectroscopic measurement [16,22].

4.2 IMPACT IN QUANTUM PHYSICS

Quantum Mechanics has more built-in realities than the Copenhagen Interpretations has allowed us to explore. This becomes obvious when one carefully analyzes the *Measurement Epistemology* developed in Section 3, especially; when one focuses the attention on understanding the physical interaction processes that give rise to the transformations we measure (observe) [21].

Let us first remove the myth that discrete "clicks" validates existence of indivisible single photons. It does not! Discrete blackened photographic grains due to Ag-halide molecules are quantum mechanical devices and respond as dipoles to only an allowed band of optical frequencies. Besides, photographic plates are made out of Ag-halide granules. All photographic images are always granular at all levels of exposures! Regarding photoelectric "clicks', one should recognize that electrons are quantized elementary particles and their binding energies are quantized in the dipoles that bound them. Photoelectron counts consist of current pulses containing billions of electrons amplified through the photo electron detection system. Valance band consists of a "sea" of electrons and the conduction band is an "empty sea". It is virtually impossible for us to claim that each measured "click" containing billions of electrons were decisively triggered by a single electron released by a single indivisible photon [21,50]!

The assumption of an indivisible photon is still an open question which has been discussed in recent papers [50, 51]. Bell's inequality, apparently validated by experiments [52,53], considered as the final proof of "single photon interference" can be challenged by using the NIL principle. For any superposition effect to become manifest, the detecting dipole must be simultaneously stimulated by all the fields generated by an n-slit grating or 2-beam interferometer. If there are n-EM fields $\vec{a}_n e^{i2\pi\nu t_n}$ simultaneously stimulating a cluster of detecting molecules, they will generate an inseparable conjoint (entangled!) set of dipolar undulations $\vec{\psi}_n = \sum_n {}^{(1)}\vec{\chi} a_n e^{i2\pi\nu t_n}$. This conjoint state is a transient state of finite duration until the detector undergoes the appropriate transformation, say, the transfer of a photoelectron from the valance to the conduction band [21]. It is meaningless to debate whether $\vec{a}_n e^{i2\pi\nu t_n}$ represents n-entangled states of a single photon, or n-classical wave packets; because, whether they are indivisible photons or divisible wave packets, they do not interact to create the transformation we measure in any optical superposition experiment.

Note that we have not presented the n-EM fields with a summation sign since they do not interact. But the dipolar stimulations are presented with a summation sign, because the energy exchange from the n-EM fields to the dipole complex is $|\vec{\psi}_n|^2$, which represents one of the most successful QM recipes. Note also that the vectorial nature of the EM field $\vec{a}_n$ has been transferred to the dipole complex as ${}^{(1)}\vec{\chi}$ to underscore the real physical operation of the EM fields on the detecting dipole. Eq.12 represents the case for the superposition of only two beams with θ as the angle between the two states of polarizations. The dipole sums its two stimulated states at the same time before it undergoes measurable transformation by absorbing energy from the two fields, which must be proportional to the square modulus of the sum of all the complex dipole amplitudes. For two simultaneous fields, we have:

$$I(\tau) = \left| {}^{(1)}\vec{\chi} a_1 e^{i2\pi\nu t} + {}^{(1)}\vec{\chi} a_2 e^{i2\pi(\nu t+\tau)} \right|^2 = {}^{(1)}\chi^2 a_1^2 + {}^{(1)}\chi^2 a_2^2 + \{ {}^{(1)}\vec{\chi}\, {}^{(1)}\cdot\vec{\chi} \} 2a_1 a_2 \cos 2\pi\nu\tau$$
$$= {}^{(1)}\chi^2 [a_1^2 + a_2^2 + \{\cos\theta\} 2a_1 a_2 \cos 2\pi\nu\tau] \quad (12)$$

Note that by using the mathematically allowed rule of taking a common constant ${}^{(1)}\chi^2$ out of the parenthesis $[\ ]$, we loose the only clue to the physical process that makes the superposition effect become manifest: the summing capability of detecting dipoles of joint dipolar stimulations induced by simultaneous presence of multiple EM fields. Focusing the attention on the term within the parenthesis $[\ ]$ and by neglecting "common factor" ${}^{(1)}\chi^2$ outside it, one can easily deceive oneself that the superposition effect arise due to direct "interference" between the light beams. The n-superposed EM fields $\vec{a}_n e^{i2\pi\nu t_n}$ are never "entangled" as light signals propagate through each other totally uninfluenced by each other. One more important point should be noted. The final energy variation in the interference (cross) term, which we register in experiments, is a product of the two separate amplitudes $a_1 a_2$ (beams splitters are never perfect)! Even basic mathematics tells us that "independent photon interference" is not what we register experimentally. In fact, LBS experiments take advantage of this product to amplify the weak signal a_2 by heterodyning with a strong local signal a_1. A deeper appreciation of Eq.12 also implies that attempts to create quantum technologies that literally rely upon generation, propagation and detection of "single indivisible photon interference", are very likely not going to work in the real world [54].

5. SUMMARY & CONCLUSIONS

We have developed a measurement epistemology, which tells us that superposition effects are always local since they always become manifest as transformations experienced by Angstrom-size detecting molecules under the influence of superposed fields. It also guides us to accept Non-Interference of Light (NIL), which in turn, tells us that time-frequency Fourier theorem should not be used as a physical principle of nature since the Fourier "monochromatic components (modes)" neither can "interfere" nor are physically realizable signal due to conservation of energy. Then, we have applied the above conclusions to a series of optical phenomena and find that they were conceptually deficient due to lack of appreciation of the above conclusions derived from our ***reality*** driven measurement epistemology.

We hope that all branches of physics would retroactively and iteratively apply our measurement epistemology to improve all of the existing "correct" theories, in stead of treating them as "final" theories. Progress in physics will become faster. At every stage of biological evolution, the DNA driven chromosomes are guided by "Natural Selection" to accept the best possible solutions. These new states (species) influence the environment and become the pre-adaptive-states for the next level of evolution; always *proactively* accepting adaptive changes on what they have already acquired. After several stages of evolution, it may appear that a different adaptive strategy could have been more efficient for a particular function. However, biological evolution does not have the capacity to retroactively correct and rearrange their genomic endowment. Human mind, although a product of such genomic evolution, has demonstrated "free will". So human mind has the capacity to *retroactively* and *iteratively* implement major corrections on our previously "successful" theories based on our enhanced understanding of the universe, which is broader and bigger in information content than when these theories were originally constructed [34, 55]. While thinking along this line of evolution, the reader may now appreciate that if the NIL-principle were not universal, the physical nature of evolution of all species with eye sights would have been dramatically different. Because, the scenes, which we image by our eyes and analyze by our brains for our survival, would have been constantly perturbed beyond our control due to "interference" induced by all other crossing light beams corresponding to other surrounding scenes!

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