Journal of Nanophotonics

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Journal of Nanophotonics, Vol. 4, 043512 (2 July 2010)

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Abstract. Non-interaction of waves (NIW) in the linear domain is an unappreciated but general principle of nature. Explicit recognition of this NIW-principle will add renewed momentum to the progress of fundamental physics and related technologies like spectrometry, coherence, polarizations, laser mode-locking, etc. This principle helps us appreciate that the mathematical correctness of a theorem and its capability to predict certain groups of measured data, do not necessarily imply that the theorem is always capable of mapping real interaction processes in nature. The time-frequency Fourier theorem (TF-FT) is an example since superposed light beams, by themselves, cannot reorganize or sum their energies. Quantum Mechanics (QM) correctly discovered that photons (light beams) are non-interacting bosons. Yet, to accommodate (i) the classical belief that light beams interfere (interact) by themselves, and (ii) Einstein's heuristic hypothesis that discrete packets of energy emitted by molecules travel as indivisible quanta (contradicting spontaneous diffractive spreading), QM has been forced to hypothesize that a photon interferes only with itself. In reality, it is the quantized detecting material media that make the superposition effects become manifest as their physical transformations, from bound electrons to released photoelectrons, after absorbing energy from all the beams due to induced simultaneous stimulations by the beams.

Keywords: Non-interaction of waves, NIW-Principle, non-interference of light.

1 INTRODUCTION

The purpose of physics is to organize diverse observed natural phenomena into a coherent theory while understanding and mapping (visualizing) the invisible interaction processes that give rise to the observables (measurables) data. The ultimate purpose is to decipher the operational *cosmic logics* behind the cosmo-spheric and biopsheric evolutions by using the power of *mathematical logics* invented by creative *human logics*. Let me identify this method of thinking as interaction-process-mapping epistemology (IPM-E). The assumption is that cosmic logics being invariant, the real physical interaction processes should also be invariant. If we repeatedly and iteratively keep on refining and/or modifying a particular theory (a set of mathematical logics) along with the basic hypotheses (human logics and imaginations), we can then keep on indefinitely improving the *map* of the interaction processes to resemble ever closer to nature's actual *reality*. However, over the last couple of centuries, we have achieved overwhelming amount of successes in understanding the behavior of nature simply by mathematically modeling the measurable data. We thought that we did not need to *waste* our efforts to understand the invisible interaction processes that create the data. Let me identify this method of thinking as measurable-data-modeling epistemology (MDM-E). MDM-E tends to treat mathematics as synonymous with physics itself rather than as a tool. Albeit being the best tool, it suffers from diverse inherent limitations, being a product of culture-driven human logics. Besides, measurable data can capture and extract only a small fraction of the reality of nature [1]. These are key reasons behind the slowdown in the progress in fundamental physics [2]. For example, the superposition principle should be written as a summation of multiple stimulations simultaneously experienced by the detecting medium; and not as the sum of the stimulating fields themselves, as we write now [3]. IPM-E tells us that we can only measure the transformations displayed by the detecting medium due to energy jointly provided by multiple fields. MDM-E missed this distinction and introduced several wrong concepts.

 [DOI: 10.1117/1.3467504]
Received 6 May 2010; accepted 24 Jun 2010; published 2 Jul 2010 [CCC: 19342608/2010/$25.00]

Epistemology of physics has major sociological implications also. Sustainable biospheric evolution critically depends upon innovation and utilization of right technologies, which started from how to create fire and light. Now we have put the light through hair-thin glass fibers, converting the distant continents into a global village. Innovations are dominantly guided by our capability to emulate interaction processes in nature. So, if we continue to ignore the interaction processes (or, IPM-E), pure mathematical models of nature will have increasingly reduced usefulness to guide human innovations and hence human evolution.

Consider the extent to which the time-frequency Fourier theorem (TF-FT) pervades our physics and engineering. Because of its successes over the last two centuries [3], we now use it as if it is a principle of nature. TF-FT tells us to directly sum light waves to obtain temporal pulses, as in mode-locked lasers, as if light beams interact (interfere). If the light beam is pulsed, we assume that linear optical systems can instantaneously respond to the mathematical Fourier frequencies even though the pulse enters into the instrument with a finite velocity [4]. Only non-linear light-matter interaction processes can generate new optical frequencies that did not exist in the original pulse. Crossing light beams never experience any changes in their fundamental characteristics unless the intervening medium responds nonlinearly to the beams. That TF-FT does not really model superposition of light beams, has been recently demonstrated using Rb atoms as sharp-band photo detector [5]. Quantum mathematics correctly implicated that light beams (photons) possess non-interacting Boson-like characteristics. But guided by MDM-E, non-interaction of waves (NIW) or the NIW-principle was ignored. We now accept the non-causal hypothesis that each indivisible photon interferes only with itself to accommodate *interference* (interaction) of light. The reality of the NIW-principle is obvious from our daily experience as can be recognized from Fig.1a. Surprisingly, this was experimentally validated (Fig.1b) by Alhazen almost one thousand years ago [6]. He found that the crossed-over and inverted images of candles, formed by a pinhole camera, remain unaltered even when he extinguished or lighted up any specific candle.

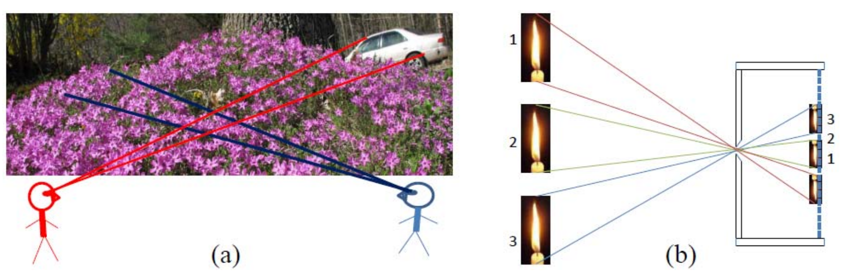

Fig.1. Non-interaction of waves (NIW) is a daily phenomenon as in (a). Thousand-year old experiment by Alhazen with candles also underscores this NIW-principle for light, which is valid for all propagating waves (undulations of tension-fields) supported by materials under tension or by electromagnetic fields.

One can imagine these candles as the distant stars whose red shifts are measured by spectrometers aligned behind telescopes to validate the hypothesis, expanding universe. If light beams interacted with each other, this validation would have been impossible since light beam from any single star is bound to cross through the light beams from trillions of other stars belonging to billions of different galaxies. In fact, light is the only energetic entity that can deliver parental information, atoms and molecules that emit light, whether they are in remote galaxies or on our laboratory table. Light-light scattering cross section in *vacuum* is immeasurably small. In contrast, particles with mass *see* each other and loose parental information as they scatter from each other. *This is why light plays a critically important role both in exploring fundamental physics and developing precision measurement tools and technologies.* However, the lack of explicit recognition of this NIW-principle creates many contradictions and paradoxes while explaining various light-matter interaction phenomena. We end up assigning many characteristics of matter to light, especially some of its intrinsic quantized behavior, which has forced us to invent many non-causal explanations like *non-locality*, *teleportation*, etc., to explain otherwise causal superposition effects. Discovering and then resolving such contradictions and paradoxes will help us develop much better maps to visualize light-matter interaction processes.

2 GENERALIZING & EXTENDING THE NIW-PRINCIPLE

Irrespective of the sustaining medium, no propagating wave packets interact with each other in the linear domain. A careful observation of two groups of water waves going in two different directions will reveal that as they propagate away from each other, they remain completely unperturbed in all of their characteristic wave properties in spite of their temporary superposition in one physical domain. Same is true for sound waves. Otherwise we could not have deciphered the words spoken by a friend at a distance standing within a noisily speaking crowd. For water waves, it is the surface tension field that undulates. For sound waves, it is the pressure tension field that undulates locally as the waves generated by some perturbation propagates away while restoring the state of equilibrium as it was before the perturbation entered. Same is true for string and percussion waves when they hold some mechanical tension field. All these waves cross through each other unperturbed as long as the *resultant* undulation amplitude of the local tension field remains within the linear domain.

These tension fields want to stay in their state of equilibrium while holding enormous amount of potential energies. A local deformation in a tension field will naturally try to get back to its original state of equilibrium provided it can get rid of the energy that has perturbed it. So the disturbed tension field tries to hand over the newly acquired excess energy, as soon as and as fast as it can, to the contiguous undisturbed tension field. Then the tension field of this new contiguous region gets perturbed. And the process continues on forever, giving rise to a group of perpetually propagating waves leveraging tension field of the new location. If the value of the tension field at a new location is reduced due to some other local perturbation(s), the velocity of the wave group will be reduced. In the absence of any cause of dissipation in the medium, the propagating wave group contains the same amount of energy that originally created the wave group. However, the wave group is not *carrying away* the energy from the original site. It is always making the potential energy of the local regional tension field become manifest as the local wave energy and becomes available for our sensors to interact with and undergo transformation to create measurable data. This model resonates remarkably close to that developed by Huygens-Fresnel principle of wave propagation (via diffraction) leveraging secondary wavelets.

Accordingly, we can assume that a group of propagating light waves become manifest when the electromagnetic (E & B) components of the cosmic tension field (CTF) are perturbed by a material dipole as it releases its own excess energy in it. Maxwell's discovery that the velocity of light is $c = 1/\sqrt{\varepsilon_0 \mu_0}$ corroborates that the electromagnetic components of the CTF are the tensions ε_0 and μ_0 of the *vacuum*. The structure of the Maxwell's wave and the string-wave equation are remarkably similar! However, unlike tension fields supported by different material media, CTF is not yet *visible* to our current sensor technologies. The highest possible value of c for light, compared to any other material based waves, implies that (i) the values of the tensions ε_0 and μ_0 of the *vacuum field* are the highest in our observable universe and (ii) the CTF holds enormous amount of potential tension energy that we must learn how to harness as soon as possible. So far, we have learned only to convert one form of *perturbation* of the CTF into another within the bounds of conservation of energy, indicating that the stable elementary particles (electrons, neutrons and protons), forming the *material* universe, mostly likely are some forms of closed-loop resonant undulations of the same CTF!

This is why various forms of field theories have been yielding remarkable successes in modeling observables. Most likely, the potential energy of CTF is the *dark energy* we have been looking for in astrophysics.

3 SCRUTINIZING A FEW OPTICAL PHENOMENA

Spectrometry: In reality, all signals are space and time finite. But, classical spectrometers have been modeled by propagating a non-causal infinitely long plane (continuous) wave through it. This gives a spectral fringe of finite width instead of an ultra narrow *delta function*, even though we have started with a single frequency. We correct this problem due to a starting non-causal model by de-convolving the *finite instrumental line width* from the measured fringe width. However, when we have a real pulse, we do the opposite to correct the problem. We mathematically find the Fourier spectrum of the pulse envelope and then convolve it with the CW fringe *spectrum* to predict the observed fringe width. Mathematically, by virtue of the Parseval's energy conservation theorem, it matches the measurement, but only when we integrate the time evolving spectral fringes with a slow detector [7,8]. A modern ps-streak camera would always reveal a time evolving fringe width. Interestingly, we tacitly assume that a *transform limited* pulse contain only a single carrier frequency under a finite envelope function; the way we always present the pictorial model for a pulse. It is clear that we should encounter many non-causal and divergence problems in all branches of physics wherever we use these non-causal Fourier frequencies of infinite duration that interact with each other to re-group their energies. The author has developed a causal mathematical model for a spectrometer by propagating a time finite pulse [3,7,8].

Nonetheless, TF-FT is very useful when it matches with the natural processes behind the phenomena we are trying to model. Let us simultaneously apply several sinusoidal potential differences across an electric circuit. Then the conduction electrons (current) will travel in the circuit as a bundled up (summed) group exactly emulating the TF-FT model. Note that an electric current is not a wave in the sense of *wave mechanics*; it is driven by an externally applied tension field, we call potential or voltage difference, which can be DC or harmonically oscillating. Electrical engineers (EE) can directly observe (measure) the amplitude of the current or the voltage as the *Fourier sum*. An optical engineer (OE) will find his measured data valid only for the time integrated TF-FT prediction; i.e., the photo detector must integrate the detected energy over a period of time longer than the spectrometer time constant. Unlike for the EE case, the OE cannot directly measure the amplitude of the light field. The difference arises because the detection processes are fundamentally different for the electrical and t optical engineers! We need to be consciously aware to match the mathematical logics with those of the *physical processes* that we are trying to model.

The Huygens-Fresnel integral (HFI), based on the summation of the forward moving secondary spherical wavelets, illustrates this point elegantly. The predicted near-field diffraction pattern is quite complex. However, in the far-field, the secondary spherical wavelets become approximately plane waves and the integral summation then changes into a space-space (from the aperture to the far-field) Fourier integral representation. In other words, the mathematical representation of the physical process behind diffraction, as hypothesized by HFI, morphs into a space-space Fourier integral representation in the far-field. Naturally, the use of the space-space Fourier theorem (SS-FT) and all the related corollaries are correct tools to model the image processing results known as the field of Fourier Optics [9].

Coherence: To explain the 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) assumes this algorithm; and it works! However, after the discovery of very fast photoelectric detectors for the visible range in 1955 [10], the theory and technology for Light Beating Spectrometry (LBS) has been established. Michelson was not wrong in modeling his *measured data*, but his *physical hypothesis* was. The mathematical correctness arises because of the long time integration of the then technology (photographic plates) that he had to live with [11].

One measures the normalized degree of coherence (autocorrelation function) $\gamma(\tau)$ from the time integrated visibility of fringes [12]. The formulation in [13] recognizes that replicated and delayed superposition of pulses, $a(t)$ and $a(t-\tau)$, with time varying unequal amplitudes, will produce time varying fringe visibility even when the pulse contains a single carrier frequency $a(t)\exp[i2\pi\nu_0 t]$. A modern ps-streak camera will show this time varying fringe visibility. 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 $\tilde{A}(f) \equiv |a(f)|^2$. We leverage the theorem of autocorrelation or 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 the two following mathematical *tricks* utilized to arrive at this result. First, the proof of the WK theorem requires the rejection of cross terms between different Fourier frequencies as if they do not interact with each other. A hidden recognition of the NIW-principle! Second, the Fourier conjugate variable for WK theorem is (ν,τ) and those for the Fourier transform for the original pulse is (f,t). Note also that t is the running time and τ is experimentally introduced physical path delay; and f is the mathematical Fourier frequency and ν is the real E-vector undulation frequency. In deriving WK theorem, we switch between t & τ and between f & ν based on mathematical conveniences with complete disregard as to what physical realities they represent at different mathematical steps [13].

Polarizations: In two-beam interferometry, if the two superposed beams, produced from the same linearly polarized CW beam, are converted into two orthogonally polarized beams by inserting two rotatable linear polarizers in the interferometer, the fringe visibility goes to zero. Logical argument is that orthogonally polarized light beams cannot produce any superposition effect, as if they are *incoherent*. 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 synthesized beam with elliptically polarized, spiraling E-vector [14]!

Mode locking: Given the NIW-principle, how can the longitudinal modes in a laser cavity, by themselves, give rise to re-grouping of the beam energy into *mode locked* pulses? Besides, why would a homogeneously broadened gain medium like Ti-Sapphire run in multiple longitudinal modes? Only inhomogeneously broadened gain media (gas lasers) runs in multi longitudinal modes because different cavity-allowed modes correspond to distinctly different sets of gas molecules with distinct set of velocities. It is the very fast time-gating properties of saturable absorber (or, Kerr medium) that allows pulsed output from the rapidly generated stored energy in well designed laser cavities [15].

4 CONCLUSION

The epistemology of doing physics has to change based on the examples of TF-FT and the ignored NIW-principle discussed briefly presented in this paper. All currently successful theories are *necessarily incomplete* as they have been formulated based on insufficient knowledge of the interactants they have modeled. We still do not know what electrons, protons and neutrons are. When a human invented mathematical theory implicates nature (cosmic logics) to be non-causal, we must refrain from taking it as the final mapping tool, especially, if it is not helping us to visualize the relevant interaction processes. While geographic maps can never become identical with the real terrain, today's *Google-maps* are remarkably closer to reality than those constructed during the fifteenth century. Same way physics needs to be redirected to create interaction-process-maps to emulate nature's reality. The author's view is that our maximum success in discovering nature's working rules, or cosmic logics, has been obtained by assuming nature to be causal. All foundational mathematical equations, which we find broadly successful, have been originally framed as representing causal relationships between cause and effect. In other words, our maximum successes have been derived by modeling nature as if it is driven by a creative but causal system engineer, and not by a whimsical deity. Accordingly, we should try to emulate nature as a system engineer and keep ourselves anchored to causality by trying to map her invariant interaction-processes. Besides, such an approach is essential for our sustainable evolution by selectively promoting biosphere-congruent technologies and concepts. Scientific endeavor must be consciously constructed towards our long journey to understand the meaning and the purpose of the cosmic evolution while maintain a sustainable biosphere [16]. We should refrain from assigning the quality of *God's equations* to any working theory. Science must not emulate the epistemology of religions that the ultimate truth has already been deciphered by our great predecessors simply because they appear to be *working*. The human species is rightfully proud of the enormous progress achieved by the successful theories of modern physics of the last several centuries. Emulating success brings more successes at a faster rate. But staying stuck in the rut of the success path *deprives us from evolving into higher planes of understanding cosmic logics*. It is time for us to move up to the next higher level of epistemology of doing science, which is IPM-E. The limit of MDM-E has been reached. It is lulling us to accept the time-frequency Fourier theorem (TF-FT) as an operational principle of nature while ignoring the existence of the universal NIW-principle in the linear domain. Sustained and remarkable successes achieved through MDM-E over the last several centuries have developed tendencies to tell nature as to how she ought to behave based on our *invention* of elegant mathematical theories. Instead we should remain focused on *discovering* real cosmic logics. However, current successful theories are our best guides. We must learn to *stand on the shoulders of the giants* and leverage their working theories to move upward. Since framing a question determines the answer we can extract out of nature, we must consciously and iteratively reframe our questions to explore the same phenomenon even when the *answer* appears to be *correct*. We should focus our attention to discover contradictions and paradoxes existing in the current successful theories. Our attempts to solve them, while anchoring our imaginations to invariant interaction processes in nature driven by invariant cosmic logics, will lead us to invent next higher level theories and discover more majestic secrets of nature than we know as of now. The process should continue indefinitely!

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