Resolving Wave-Particle Duality could accelerate the mass production of Quantum Computers

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ABSTRACT

Quantum computers, hypothesized in 1980s, use concepts of superposition and entanglement phenomena. Although theoretical propositions and associated search algorithms for accurate measurements are being generated, the development of practical quantum computers themselves are advancing very slowly requiring enormous time and investments. The underlying concepts of a quantum computer are not new to the optical domain. However, the crucial enabling concepts of Entanglement and Superposition Principle are remaining clouded under the unresolved postulates, Wave-Particle Duality (WPD), and Wave Packet Reduction (WPR), implicating incompleteness in the interpretations of the mathematical formalism behind Quantum Mechanics. The WPD debate started during late1600 between Newton and Huygens. Young's resolution of WPD through his double-slit experiment in 1802 was effectively overturned by Einstein's interpretation of photoelectric effect as due to "indivisible light quanta". However, Einstein disowned his "light quanta" postulate shortly before his death in1955, even though it had earned him the Nobel Prize. We resolve WPD by synthesizing Newton's and Maxwell's concepts and assume atoms do emit quanta but propagate as time-finite exponential pulses. This assumption also resolves WPR for light-matter interaction with the assumption that Schrodinger's ψ represents atom's internal dipolar amplitude stimulations. This over-turns Born's interpretation that ψ only represents the abstract mathematical probability amplitude, rather than the physical "internal amplitude stimulation" of the quantum entity. However, our concept of atomic pulse emission forces us to re-derive the expression for the N-slit grating-spectrometer response since the classical derivation uses CW light, which does not exist. This pulse-spectrometric response function strengthens our postulate since the grating response to the exponential pulse appears to be the convolution of a Lorentzian spectrum with the classical CW response function of the grating. The Fourier Transform of an exponential function is Lorentzian and QM predicts spontaneous emission line width to be Lorentzian. Then, conceptually one can extend the grating-expression (with N=2) to get the double-slit pattern. This approach preserves the classical causality that each of the two slits, like the N-signals out of a grating, are physically real and jointly stimulate the quantum detector array at the far field to generate the "Local" cosine fringes. The detector array executes the square modulus operation on its imposed dipolar amplitude stimulation and absorbs the necessary energy to fill up their quantum cups. Hence the double-slit pattern must also be "Local", just as the N-slit grating spectrum is generated locally at the exit spectral-plane of the spectrometer. This removes the need to believe that "single photons" mysteriously generate the double slit pattern.

Keywords: Superposition Principle; Superposition Effect; Resolving Wave-Particle Duality (WPD); Wave-Particle reduction; Locality of Superposition Effect due to active role of a detector; Reality of light-detector interaction process; Reality of multiple optical signals in superposition effect; Photoelectric current pulse (PCP) generation.

1. INTRODUCTION

The latest issue of the IEEE Spectrum of 2023 ran an article, "*Quantum Computing's Hard, Cold Reality Check: Hype is everywhere, skeptics say, and practical applications are still far away"* [1, 2]. Those readers who are interested in seeing

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the current state of technology behind Quantum Computer, should consult Appendix A at the very end of this article. Charles Kao presented the concept of Global Fiber Optic Network in 1960 by demonstrating a low-loss single mode fiber. By 2000 the concept has become a global reality. It took 40 years. The concept of quantum computers was proposed by David Deutsch in 1970. It is now over fifty years and yet we do not have any commercial products for the mass market. We need to accept that there are some serious conceptual issues that need to be explored. Accordingly, our intention is to explore and discuss the fundamental physics issues relevant to "photons" and "photon counting", which is one of the approaches to creating quantum computers.

We have been introducing ad hoc "contextual interpretations" for various quantum mathematical equations to explain the meaning of the measurable data. Relevant to our problem for this paper are – Wave-Particle Duality (*WPD*) and the Wave Packet Reduction (*WPR*) [3-8]. A causal understanding of WPD and WPR has become confusing because of the following two reasons. First, the negligence in recognizing explicitly the Non-Interaction of Waves (NIW) [9]. Second, our negligence in not incorporating explicitly the appropriate *interaction parameter* of the detector that executes the data generating interaction process. [See C.12 in 9; 10, 11]. We believe that these conceptual incompleteness and contradictions have been allowing the persistence of the conflicting and non-causal interpretations of "Entanglement" in the measurements of two-beam superposition effects, like the double-slit and the Mach-Zehnder Interferometer. Our purpose is to develop a path towards deeper and clearer understanding of the interaction processes between light and detector due to superposed light beams. These detector signals ultimately allow the innovation of the proper engineering approach that can process computational algorithms.

The WPD has been promoting the mystification of the EM waves as unfathomable "indivisible light quanta", or photon, as if EM energy propagates as energy bullets ($h\nu$), rather than diffractively propagating Maxwellian wave amplitudes. The combination of the WPR and the normalizability of the quantum wave function has given birth to the general concept of "Entanglement", and "entangled photons" as a byproduct [4, 12]. Therefore, the attempts to make causal interpretation of nature has become overwhelmingly difficult when the intensity of the incident light beam is deliberately made very low so that one can only count the probabilistic (time random) photoelectron current pulses (PCP) emerging out of very complex electronic amplification system. PCPs are actually very short current pulses, consisting of hundreds of millions of amplified electrons, generated out of the original single photoelectron. Should we identify the PCPs as the Einsteinian photons?

The original concept of the Quantum Computing (QC) algorithm leverages the mathematical Amplitude Superposition Principle (A-SP), while using the causally inexplicable concepts of WPD and WPR, already mentioned above. Our intention is to first present potential solutions to these two concepts. We are postulating that excited atoms, holding the deliverable energy $h\nu$, behaves as a real physical excited Hertzian dipole (no need for WPR) and emits an exponentially decaying Maxwellian wave packet (no need for WPD). This light pulse contains the QM predicted energy hν, with the E-vector oscillating at the carrier frequency ν, and propagates out diffractively spreading, following the Huygens-Fresnel Diffraction Integral (HF-DI), which has been introduced as early as 1817 by Fresnel [13, 14]. The release of a quantum mechanically bound electron inside a photodetector is also an amplitude-amplitude dipolar stimulation process [15, 16]. The stimulation is initiated by the classical Maxwellian light pulses, having frequencies within the right quantum band of the material such that a quantum mechanically bound electron can absorb the necessary energy $h\nu$, which must be greater than its quantum mechanical binding energy. This does corroborate Einstein's energy-balancing photoelectric equation; but the equation itself does not incorporate the phenomenological light-matter amplitude-amplitude stimulation process before the resonant energy exchange can take place [4, 15]. The proposed exponential pulse for the photon [17] is corroborated by the fact that all the measured spectral linewidth of spontaneous emission appears to be Lorentzian in the sub-GHz domain.

The key phenomena that keep people excited about possible construction of Quantum Computer (QC) using single photons are the Superposition Principle (SP) and its derivative, Entanglement. Therefore, we will dominantly focus on understanding how we generate data out of superposition effect using detectors. As already mentioned before, the key overarching concept we are using is the Non-Interaction of Waves (NIW) [9], meaning a detector's interaction parameter must multiply the optical signals that stimulate the detector for the generation of data. NIW was experimentally demonstrated as early as 1080 by Alhazen [18] and coopted as a principle of nature by Huygens in his famous 1690 book on light [19]. NIW implies that the measurable superposition effect, implied by the summation operation, is shown in $E_1+E_2=E_{fnl}$, cannot take place spontaneously. Otherwise, our human vision of the surrounding scenery, or telescopic view of the outer universe, could not have been imaged as spatially separate and clearly identifiable, even though all the light is collected through a common aperture. This is well known, but we have been ignoring it. Therefore, the mathematical operator "+" must be executed by some active physical "detector", whose interaction parameter determines the final detectable physical transformation displayed as "data" in our instruments after absorbing energy out of all the stimulating amplitude signals. For light matter interaction, the dipolar polarizability is the interaction parameter, and the detectable amplitude Superposition Principle (SP) should be written as, $\chi_1 E_1 + \chi_1 E_2 = d_{amp.}$, where $d_{amp.}$ signifies the detector's amplitude stimulation induced jointly by the two physically superposed signals on it. Recipe for the detectable energy transfer, by both the classical and the quantum physics is the square modulus of the sum of the amplitude stimulation or the detected energy, $D = |d_{amp.}|^2 = |\chi_1 E_1 + \chi_2 E_2|^2$. This is the measurable Superposition Effect (SE). For light-matter interaction, χ_1 is the linear dipolar polarizability of the detecting molecules, which are also susceptible to higher order stimulations quantified by χ_n's. They are usually very weak, and for engineering data, we tend to ignore but they are never zero. Therefore, we should not develop mathematical theories without considering this physical reality. The interaction parameter is the key to the generation of useful and recordable engineering data. Further, the detector must be frequency-resonant to all the superposed signals. That is how we select photodetectors having a peak resonant detectivity for the chosen frequency of light.

Since the individual Maxwellian exponential pulses propagate spreading out diffractively, they cannot any more deliver their full energy hν to Angstrom size atoms, unless they are within a very special micro-cavity for QED studies [20]. Therefore, the energy $h\nu$ necessary for the absorption to release one photoelectron happens through the joint stimulations induced by multitudes of time and phase random and amplitude changing exponential pulses. Then the classical superposition principle and the statistical coherence theory become fully capable of explaining the statistical behavior of the registered photoelectron current pulses (PCP). The stimulated dipolar quantum entities, holding the electrons, can be conceptualized as energy harvesting quantum cups [9], seeking out $h\nu$-quantity of energy out of many superposed time and phase random pulses [21-23]. Therefore, the statistical light pulse emission characteristics, like laser vs. thermal sources, should help us explain the observed statistics of photoelectric current pulses (PCP). It is difficult to imagine that pure temporal distribution of the emission instants of Einsteinian "bullet photons" can fully explain the variation in the PCP statistics generated by thermal, laser and nonlinearly generated radiations.

1.1. Flow of the paper

Section 2 presents the explanations to understand most of the observed responses of modern quantum photodetectors to light using our proposed model of atomic emissions as Maxwellian exponential pulses. Specifically, Section 2.1 defines the "quantum photons" emerging as exponential pulses. Section 2.2 pictorially explains the origin of photoelectron statistics. Section 2.3 pictorially explains the classical reason behind the spatial "granularity" in pictures generated by photographic plates and CCD cameras. Section 2.4 pictorially explains the origin of the temporal granularity, or the statistical behavior of the photoelectron current pulses (PCP). These observed granularities have been used as one of the vital reasons behind promoting the discrete energy "photon" model.

The Section 3 provides the summary of the spectral response of an N-slit grating spectrometer to an incident pulsed light, which supports our postulate that the "quantum photons" propagate out as Maxwellian classical exponential pulses, rather than Einsteinian bullets. Our analysis supports that the measured spectral fringe should have the Lorentzian characteristics (a Fourier transform of the exponential pulse). The analysis, illustrated by cartoons, also underscores that the spectrometric data is due to the Superposition Effect registered by a detector array due to N-real signals stimulating it [see Ch.5 in 9, 24 and 25]. Therefore, one can conceptually cover up the grating with a screen, leaving only two slits open. The result will display the famous Young's double-slit pattern. This is another way of removing the misconception that the double-slit is a mysterious quantum phenomenon generated by individual bullet photons. If the signals from each of the two slits are physically real, carrying multiple space and time evolving optical parameters (amplitudes, phases, frequencies, polarizations, etc.), such signal-amplitudes cannot be arbitrarily normalized to generate the desired one-count of photon after the detector executes the square modulus operation on the two complex amplitudes. However, this mathematical trick appears to be a critical step towards obeying the condition of Bell's Theorem, as well as Schrodinger's "Entanglement". We close this section by underscoring that the "photon" (our exponential pulse) is a solution of the classical Maxwell's wave equation. It is not a solution of the Schrodinger's "quantum wave" equation. We should not assign the quantum superposition principle valid for of the Schrodinger's solutions on to those for Maxwell's classical wave packets.

2. PHOTOELECTRON CURRENT PULSE (PCP) IS NOT A PHOTON

2.1. Defining the "Photon" as an Exponential Pulse.

During the late 1880's Hertz experimentally validated Maxwell's theory of EM waves of 1876 by generating and detecting EM waves using macro dipoles. Later dipolar antennas were used to routinely generate and detect radio waves. Even today's cell phones operate using very compact dipolar antennas. There is currently intensive work going on to design and construct nanoscopic dipole antennas for visible light [26]. Given this sustained background of successes of the antenna model, it is difficult to assume that nature suddenly has switched to a "black box" model for atomic emission as the "Wave Function Collapse" (WFC), as is accepted by the prevailing dominant interpretation of QM. This also contradicts the prevailing practices and publications on light-matter interactions where the light-matter stimulation is formulated as a dipolar stimulation [27]. Therefore, we are postulating that atomic emissions do constitute Hertzian dipolar emission over a finite period [28]. The classical generic dipolar decay is exponential [22, 23]. By time-frequency Fourier theorem (TF-FT), the atomic pulse duration Δt would be around 1ns to 100 ns for Δν ~1GHz to

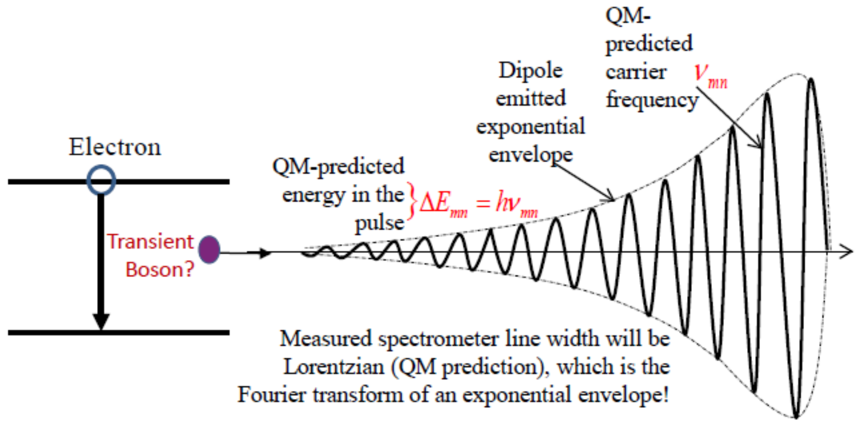


Figure 1. The semiclassical model of a "photon" wave packet. It is a time finite Maxwellian wave packet with an exponential envelope, which corroborates the Lorentzian spectral line width of spontaneous emissions, as measured by a classical spectrometer. However, it has a single carrier frequency ν and a total energy hν [28].

10MHz. Accordingly, we have defined the atomic exponential emission as shown in Fig.1. To conform to the well-validated QM predictions, we are assuming that the total energy content under the mathematical exponential envelope equals hν, with a precise and single carrier frequency ν. However, the mathematical TF-FT implies a Lorentzian *frequency* spread. We will resolve this very important contradiction of classical physics in Section 3, while explaining the Superposition Principle from the engineering viewpoint. Here we simply underscore that TF-FT is a mathematical theorem, not a principle of nature.

Therefore, we must remain vigilant about how and where we use mathematical Fourier theorem to explain natural phenomena. Classical spectrometers are linear light beam replicators. They cannot execute TF-FT algorithms on a time finite input pulse propagating through them with a finite velocity. One needs to use some complex electronic instruments designed to execute all the steps implied by the mathematical FT algorithm.

2.2. Generation of Photoelectron Current Pulse (PCP).

It is important to appreciate the roots of successes of Einstein's original presentation of the photoelectric equation:

$$h\nu = \phi_{work\ fn.} + (1/2)mv_{el.}^2 \tag{1}$$

This equation represents the energy balancing relation to match the already published data in Fig.2a, showing a linear increase in the velocity of the released electrons in the *free space* with the frequency (horizontal axis) of the stimulating radiation. No photoelectron is emitted below a certain threshold frequency. Einstein underscored in his 1905 paper that there is a quantumness in light to explain the observed threshold in Eq.1. Rigorous measurements by Millikan validated the energy balancing Eq.1. Unfortunately, Einstein assigned the quantumness to Maxwell's classical waves, but not to the quantum mechanically bound electrons, perhaps, thinking of Planck's "quantum" concept (1901). However, Planck's quantum postulate underscored that the emission and the absorption of electromagnetic energy by materials happen in discrete quantum of energy hν for given frequency. Inside the Blackbody cavity, the emitted radiation quickly reaches the equilibrium energy density via the classical diffractive process. However, Einstein was eight years ahead of Bohr's model for Hydrogen atom published in 1913, which formulated that the electron in the Hydrogen atom can occupy only discrete *quantized energy levels*. This concept was generalized by the formalism of Quantum Mechanics in 1925 and 1926. However, by this time Einstein's quantized photon took a very strong life of its own within the community, including the quantization of electromagnetic field (QED) by Dirac [29] and others. However, the classical optical community has been advancing the field of optical science and engineering by propagating light using Maxwell's equation-set.

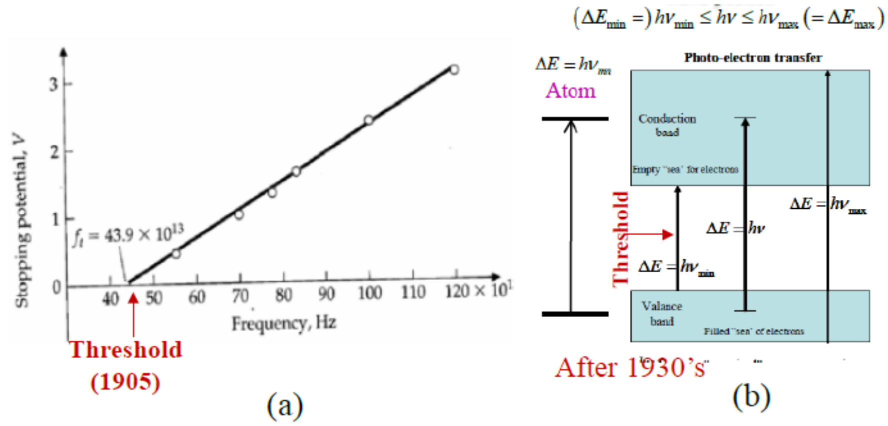


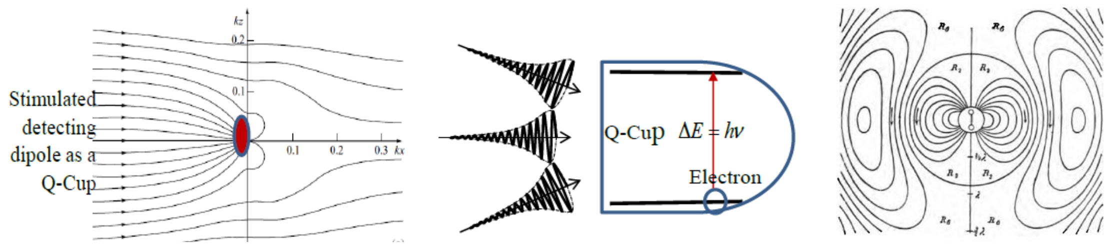
*Figure 2. **(a)** Linear velocity change of extracted photoelectrons with the frequency of the illuminating light. Below some frequency there is no emission of photoelectrons. This quantumness is due to electrons in material being bound quantum mechnaically; not because light is indivisible energy bullets. **(b)** After the development of QM people understood that electrons in atoms and materials are always bound quantum mechnaically. The zero crossingin of the linear curve in (a) from the band-diagram in (b), where the shortest vertical arrow shows the value* $\Delta E = h\nu_{\min}$. *[Fig.2(a)is from the book "Modern Physics" by Bernstein et al.].*

Let us now briefly summarize what constitutes counting a photoelectron current pulse (PCP) using a modern photomultiplier tube or a solid-state photon counter [7]. The commonality in these two "photon" counters is that the single initial electron, released by absorbing the necessary quantum of energy hν out of the incident electromagnetic waves, is amplified into a measurable photoelectron current pulse (PCP) containing some 10^6 to 10^9, or so electrons. These current pulses have some finite time duration and enforce "dead time" intervals on the electronic amplification system. Any new photoelectrons released during these dead intervals would not be counted. The key point is that PCPs cannot directly validate the quantization of electromagnetic waves. PCPs do not represent "quantum photons" even if they existed. The "threshold frequency" that triggered Einstein's equation can now be generically appreciated from the band diagrams of current solid-state physics, shown in Fig 2b.

The key limit of Einstein's photoelectric equation is that it does not incorporate the phenomenological process of light-matter interaction and hence the stimulation process - the electric vector of the incident field stimulates the atomic/molecular dipole cluster holding the electron quantum mechanically. This approach is standard in atomic and molecular physics. We also need to incorporate the frequency sensitive polarizability factor $\chi(\nu_q)$ to be congruent with engineering detectivity of the detector we use.

$$\left\langle \left|\psi_{res.}(t)\right|^2 \right\rangle_{ensm.} = \left\langle \left|\sum_q \chi(\nu_q) E(\nu_q, t)\right|^2 \right\rangle_{ensm.} \Longrightarrow \left\langle h\nu_q \right\rangle_{ensm.} = \left\langle \phi_{work\ fn.} + (1/2) m v_{el.}^2 \right\rangle_{ensm.} \quad (2)$$

The left section of Eq.2 symbolically underscores our point that stimulating EM waves consists of diffractively spreading exponential wave-amplitude packets $E(\nu_q, t)$, which must be frequency-resonant to the dipolar binding structure of the would-be photoelectron. Resonant amplitude-amplitude stimulation is the first step before the detector executes the square modulus operation to absorb the quantum of energy hν out of the innumerable time and phase random partially superposed exponential pulses. The counting statistics requires ensemble averaging, as prescribed by QM formalism.



(a) **(b)** **(c)**

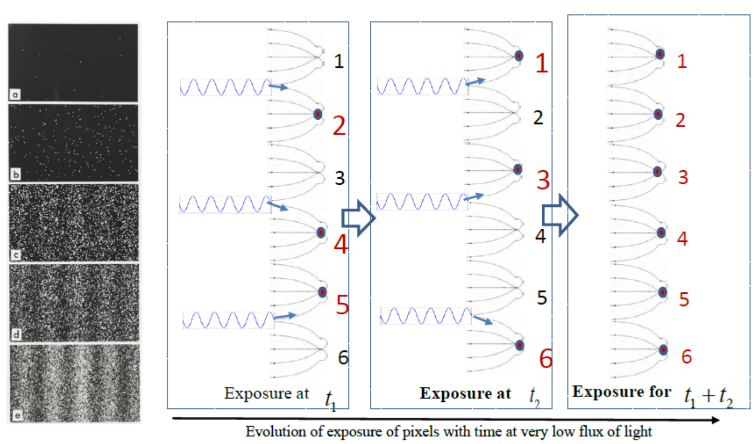
Figure 3. A resonetically stimulated Angstrom size atom, in (a) projects a very wide set of stimulated lines of force, like a quantum cup, to pull in the necessary cup-filling energy hν out of multitudes of Maxwellian exponential pulses passing through. This is depicted in the cartoon (b). Cartoon (c), is the Hertz-model for a spontaneously emitting dipole [5, 22].

It is important to recognize that individual atoms have the dimension of one angstrom. An Angstrom-cube atom is too small to acquire the necessary hν quantity of energy out of the diffractively thinned out field. Even a visible laser beam, of diameter 1mm, transporting 1mW He-Ne red laser power, can provide only $8.6\text{x}10^{-18}$ photon-equivalent energy within one Angstrom-cube volume. This clearly implies that the energy seeking resonant dipole, when stimulated, opens as a very large quantum cup, as depicted in Fig. 3(a) and (b). In fact, this is well-understood classical physics and is used for designing radio and cell phone antennas. The physical size of our cell phone antenna has too small a footprint to absorb the necessary energy to keep working without extending its resonant dipolar cup.

2.3. Spatial Granularity in PCP Registrations.

The granularity (spatial and temporal) in the records of light signals at very low light levels has been used as one of the major driving factors to justify the "indivisible light quantum" model. See the Nobel lecture by Glauber [30]. Fig.4a shows a well-known spatial record of building up of the double-slit cosine fringes with increasing steps of exposures. We should note that whether it is a photographic plate or a modern CCD camera, they are constructed out of miniscule Ag-Halide grains or photosensitive electronic pixels. Therefore, when such images are highly enlarged, whether generated via a short exposure with high intensity illumination, or long exposure with very low intensity illumination, will always show spatially distinct grains. Fig.4b pictorially explains the role of the process of quantum probability that creates a competitive competition between the neighboring dipolar quantum cups projected by the densely packed detecting elements. When the flux density is very low (implied by only single pulses), one of the quantum cups succeeds in harvesting the necessary hν quantity of energy, while depriving the immediate neighbor. However, once its Q-Cup is filled, it no longer competes for any further energy. The flowing-on low flux energy then becomes available to the previously deprived Q-cup of the neighboring element. The evolution of the sequential progress in exposure at very low light is pictorially explained in the three vertical rectangles of Fig.4b.

The key point to note is that it is *the quantumness of the light absorbing detector*, which creates the granularity. *It is not because light is granular*.



(a) (b)

Figure 4. Understanding spatial and temporal granularity in photographic records. (a) Shows the copy of an experimental photographic record for a succession [31]. The temporal granularity can be understood from the quantum statistical behavior of competition between the neighboring detecting elements at very low amplitude flux, and hence energy flux. Recall that detecting elements execute the square modulus operation on the incoming stimulating fields before they can fill up their quantum cups.

2.4. Temporal Granularity or PCP Statistics.

The next issue of understanding the origin of the temporal PCP statistics is more subtle. Our model of light is exponential pulses that are always diffractively spreading out. Therefore, no single pulse can provide the necessary quantum of energy to fill up the frequency-resonant quantum of energy hν to any detecting element. There must be multitudes of pulses to help fill up the quantum cup of each detecting element, even if the energy harvesting duration is 1ps or less. The concept of filling the quantum-cup cannot override the finite velocity of light. Light detecting dipoles will experience the time-varying amplitude stimulations. Each detecting entity will perceive a flow of amplitude stimulating signal that can be given by the Eq.3 and the corresponding mathematical flow of intensity, modulated by the time-varying amplitudes of individual pulses and phases as a superposition effect. It can be given by Eq.4. This equation, as it contains many, many pulses, will generate many pulse autocorrelation factors, which can be computed because the temporal pulse shapes, in free space propagation, are the same exponential envelopes. The phases will be perfectly random for thermal sources and partially random for laser sources. The effective number of hν quantity of energy packets that would be available to the detecting elements could be given by the Eq.5. We have used the approximately equal sign ≈ to indicate that Maxwellian waves, after diffractive propagation, cannot anymore deliver the full hν quantity of energies to angstrom size atoms.

$$\psi_{res.}(t) = \sum_q \chi(\nu_q) E(\nu_q, t); \quad E(\nu_q, t) = a(t) e^{i(2\pi\nu_q t + \phi_q)} \tag{3}$$

$$I(t) = \left|\psi_{res.}(t)\right|^2 = \left|\sum_q \chi(\nu_q) E(\nu_q, t)\right|^2 \tag{4}$$

$$N \approx \left[\int_{\delta t} I(t)dt\right] \Big/ h\nu \tag{5}$$

Thus, one can now start modeling the origin of the characteristic statistics in the photoelectric current pulses (PCP). They are influenced due to variation in the temporal amplitude in the exponential pulse shapes, their temporal arrival positions due to random emissions, and the differences in their phases. For lasers, the phases are mostly the same; but since their origin is due to stimulated emissions triggered by different atomic pulses, lasers do have some phase fluctuations, albeit much less than thermal sources. We present this conceptual model from the cartoon in Fig.5. This model, when carried through by computations, should validate the measured PCP statistics that are already known through measurements [32, 33].

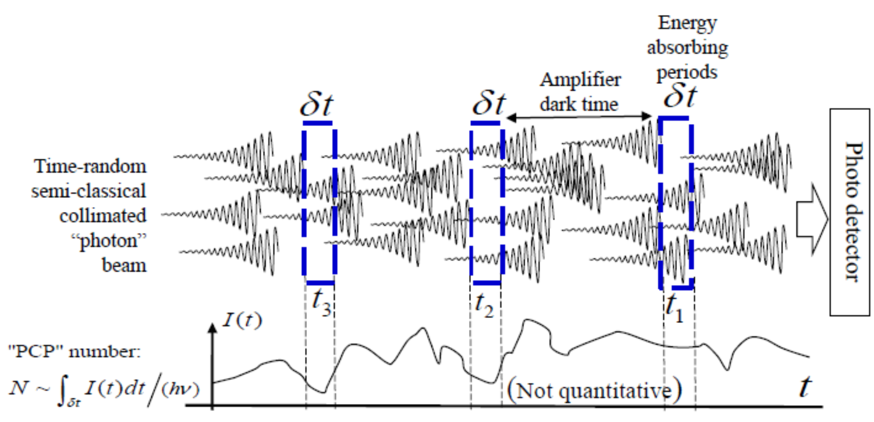


Figure 5. Conceptual presentation of the propagation of time and phase random exponential pulses through a photodetector, depicted as a vertical rectangular box on the right. The bottom wiggly curve indicates the mathematical flow of intensity (not quantitative) as would be perceived by the detecting dipoles. This can be computed from the superposition Eq.3&4 [31]

It has been experimentally found that the second order non-linearly generated sources using lasers, show a narrower spread in its PCP statistics than the spread shown by the laser in direct measurement. We believe that this is understandable using our conceptual model and the physics of nonlinear conversion. The light amplitude generated through the second order nonlinear process is [34]:

$$E_{2nd\ order}(t) \propto \chi_2 E^2(t) \Rightarrow I_{2nd\ order}(t) = \chi_2^2 E^4(t) \tag{6}$$

Therefore, the temporal variation in the effective intensity of the output signal, $I_{2nd\ order}(t)$, will be significantly smoothed out due to the $E^4(t)$ dependence. We should comment further that such second order light sources have very little to do with QM. This is because not only the initial stimulating signals are Maxwellian exponential pulses, but also because the very physical processes behind most nonlinear conversions are carried out using classical bulk crystals, where the efficiency depends upon the length and the effective volume of the crystal that are participating in the conversion process. There is no quantum level or quantum band transition involved in nonlinear optical conversion process, such as optical parametric oscillators, where we use a focused laser beam through macro crystals of certain length. In contrast, the emission of photoelectrons is a quantum mechanical process.

3. OBSERVABLE SUPERPOSITION EFFECT IS LOCAL, GENERATED BY A DETECTOR

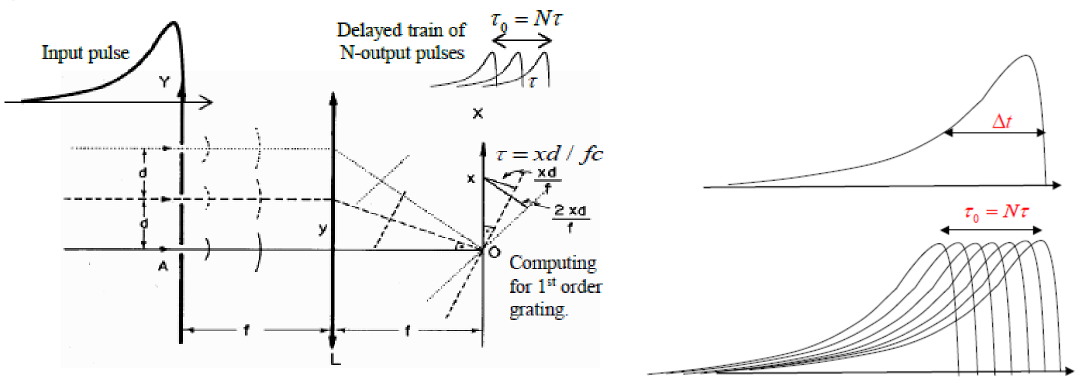
In Section 2, we have shown that photons can be understood as classical exponential pulses that can also explain all the observed photoelectric effects, including PCP statistics. We also underscored that PCP's should not be misconstrued as discrete photons. We do not count photons. We count photoelectron current pulses consisting of hundreds of millions of electrons amplified through electronic amplifications. In this section, we will establish that the choice for the model of quantum photon as classical exponential pulses is of fundamental importance. Because a mathematical theory, corroborated by the measured data may not always model actual interaction processes of nature, which is the actual goal of physics. This is a fundamental problem of current physics thinking as we have started to believe that the universe is built out of *information* represented by equations. However, information is our interpretations of the measured data or the observed facts. Our knowledge about the universe is still limited as we gather the data to validate mathematical models of natural phenomena. Data is generated by our instruments through some *interaction process* between a signal under investigation and some sensor whose properties we are supposed to know. We must remain alert to incorporate the appropriate *interaction parameter* in our theories that will model nature's *interaction process*, which generates the data. We have underscored this point in the context of explaining the limitation of Einstein's photoelectric equation in our Eq.2. Einstein's photoelectric equation correctly validated the measured velocities of the released electrons, but it does not explain the first step of stimulation of the electron-holding dipole by the frequency of oscillation of the E-vector of the light wave.

In this section, our first objective is to validate that our exponential pulse model to seamlessly integrate with all other requirements and measurements of light. First, the "pulse" concept corroborates Newton's "Corpuscular" proposal based on his understanding that energy-finite miniscule atoms can emit only a finite amount of energy. It is a classical wave pulse and hence it corroborates Huygens Principle, which is further strengthened by Maxwell's electromagnetism. It also corroborates the predictions of Quantum Mechanics since we are assuming that the energy contained in the pulse is hν and the carrier frequency is the QM predicted ν. However, it gives rise to a major conflict with the current interpretation of the frequency content of a light pulse. The prevailing belief in classical optics is that a pulse of width δt has a spectral distribution δν by virtue of the well validated Fourier theorem. A pulse $a(t)\exp[i2\pi\nu_0 t]$ has a spectral content $\tilde{a}(f-\nu_0)$ centered around ν_0; $\tilde{a}(f-\nu_0)$ is the FT of the pulse $a(t)$. In other words, the temporal pulse function $a(t)$ and the spectral function $\tilde{a}(f-\nu_0)$ conform to each other as a Fourier transform pair. But we are claiming that the source-generated frequency ν_0 remains unchanged through our spectrometers, whose response is linear to the incident light waves. In the process of resolving this conflict, we realized that the mathematical theory of classical spectrometry has been derived using a CW wave. However, from the standpoint of strict causality, combined with energy conservation, a CW wave cannot exist in nature. All light sources are energy-finite and have finite lifetimes. That is why we have derived the pulse response function for the grating and Fabry-Perot spectrometers [See Ch. 5 in 9, 35]. Here we will present only the key mathematical steps for the convenience of our discussion and explain why our concept of photon as an exponential pulse is valid even from the standpoint of classical spectrometry.

We have also added a sub-section on the famous Young's double slit. The purpose is to underscore the reality of the two signals propagating through the two slits that generate the double-slit pattern in the far-field. The concept of "single photon interference" has been strongly promoted using the generation of double slit patterns. In Fig.4a we have presented an example, where we have explained the origin of granularity from the very composition of the detector array and the quantumness of the detectors. For the theory of N-slit grating spectrometry, even though the classical theory was derived by using a CW wave, as in Young's double slit, everybody mathematically propagates *N-real signals* through the spectrometer and *N-diffracted beams jointly expose the detector array* to create the spectral energy distribution [36] placed on the output (spectral) plane. Therefore, in Section 3.2 will use the N-slit grating equation, after substituting N=2 to derive Young's double slit pattern. We will also show the cartoons for old alternate methods by which people had generated two-beam superposition effect where the spatial extent of the two beams do not fully overlap. They found that the fringes appear only in the domains where parts of both the beams are physically overlapped. No fringes appear where the signal from only one beam is present. One photon does not interfere with itself. Even our mathematical equations always show 2-terms or N-terms for 2-beam, or N-beam superposition effects to emerge on a detector array.

3.1. *Classical N-Slit grating spectrometry with exponential atomic pulses*.

In this section, we will present the key summary-steps behind the theory for a grating spectrometer [37] when it responds to a single generic pulse to justify our choice of photon as an exponential pulse with a carrier frequency ν, as has been set forth by QM.



(a) **(b)**

Figure 6. Derivation of the pulse-response function for a grating spectrometer since all atom/molecule emitted light must be time-finite pulses. We have used the Huygens-Fresnel diffraction model for a grating spectrometer illuminated by an exponential pulse. (a) Shows the generation and physical superposition of N-periodically tilted plane wavelets at the spectrum-recording plane where a detector array records the spectrum. The sketch in (b) shows the condition when the incident pulse length Δt is close or greater than the total delay between closely spaced N-delayed pulses. Under this condition our formalism becomes equivalent to the classical derivation using the CW light.

The sketch in Fig.6a emulates the concept of the Huygens-Fresnel diffraction principle. The N-slits are in the Y-plane and the spectrum is recorded on the X-plane situated in the "far-field" simulated by using a convex lens, such that the Y-plane and the X-planes are separated by distance equal to the focal length of the lens. Under this condition, each of the Huygens secondary wavelets converge on the optical axis as a series of equally tilted plane waves with a periodic delay shown in the cartoon. If the periodic temporal delays between the consecutive plane waves at the detection spot "x" is τ, then the amplitude stimulation $d_{out}(t)$ induced by the N-signals on a detector with a responsivity χ(ν) can be expressed as Eq.7. We are assuming that each slit transmits $a(t)/N$ amount of amplitude.

$$i_{out}(t) = \sum_{n=0}^{N-1} (1/N)\chi(\nu)a(t-n\tau)\cdot\exp[i2\pi\nu(t-n\tau)] \tag{7}$$

$$I(t) = \chi^2(\nu)\left|\sum_{n=0}^{N-1} (1/N)a(t-n\tau)\cdot\exp[i2\pi\nu(t-n\tau)]\right|^2 \tag{8}$$

While χ(ν) is only a number unique to a specific detector, its functional importance is that the detector executes the summation as its stimulation by all the N-signals. Recall that waves do not sum themselves or interact with each other to generate the superposition data; the detector does that. The time-varying intensity will be simply the square modulus of

Eq.7, given in Eq.8. After the execution of the square modulus operation, as in Eq.8, one can obtain the time-integrated energy, Eq.9, where the all-possible pair-wise autocorrelation of then N-pulses is given by $\gamma(|m-n|\tau)$ in Eq.10:

$$\mathrm{E}_{pls}(\nu,\tau) \equiv \int_{-\infty}^{\infty} |\, i_{out}(t)\,|^2 dt = \frac{\chi^2}{N} + \frac{2\chi^2}{N^2}\sum_{m\neq n}^{N-1}(\gamma(|m-n|\tau)\cos[2\pi|m-n|\nu\tau] \tag{9}$$

$$\gamma(|m-n|\tau) \equiv \int a(t-n\tau)a(t-m\tau)\ dt \Big/ \int a^2(t)\ \ dt \tag{10}$$

To validate the rationality of our model behind deriving the pulse-response function of Eq.9, we need to show that as the incident pulse becomes longer and longer, the Eq.9 should keep approaching the classical CW expression for a grating. We did find that when the width of incident pulse becomes much larger than the duration of the output N-pulse train, or when $\Delta t \gg \tau_0 \equiv N\tau$. Under such conditions, one will find that all the normalized pair-wise autocorrelation factors $\gamma(|m-n|\tau)$ in Eq.9 and 10 approaches unity. Then, after some algebraic manipulations, Eq.9 reduces to the classical CW expression, as in Eq.11 below.

$$\underset{\Delta t \gg \tau_0 \equiv N\tau}{Lt.}\ \mathrm{E}_{pls}(\nu,\tau) = \frac{\chi^2}{N} + \frac{2\chi^2}{N^2}\sum_{m\neq n}^{N-1}\ \gamma(|m-n|\tau)\cos[2\pi|m-n|\nu\tau] \Longrightarrow \mathrm{E}_{cw}(\nu,\tau) = \frac{\chi^2}{N^2}\frac{\sin^2 \pi N\nu\tau}{\sin^2 \pi\nu\tau} \tag{11}$$

Further, by using Parseval's energy conservation theorem for a conjugate Fourier transform pair, one can also show that the time integrated spectral energy spread function can be expressed as the convolution of the spectrometer's CW response function with the Fourier spectrum of the temporal pulse envelope:

$$\mathrm{E}_{pls}(\nu,\tau) = \int_{-\infty}^{\infty} |\, i_{out}(t)\,|^2 dt = \mathrm{E}_{cw}(\nu) \otimes \tilde{A}(f) \tag{12}$$

Eq.12 tells us that the *measured* spectral response of a grating spectrometer due to an input pulse $\mathrm{E}_{pls}(\nu,\tau)$, derived directly as the grating pulse response function in Eq.9, can also be expressed as the convolution of the CW-response function $\mathrm{E}_{cw}(\nu)$ with the abstract mathematical Fourier frequency function. If $a(t)$ exponential, then $\tilde{A}(f)$ is Lorentzian, which is the experimentally observed result, and can be recovered after deconvolution of the CW instrumental response function $\mathrm{E}_{cw}(\nu)$ from the $\mathrm{E}_{pls}(\nu,\tau)$. QM also predicts that the atomic spontaneous emission line width is Lorentzian. Thus, we have validated that our postulate of spontaneous atomic emissions consisting of exponential pulses [35] is perfectly congruent with the *traditional* spectral measurement theory.

3.1.1. Mathematical Fourier transforms in optics and connections to reality of measurements.

Reader should note that $\tilde{A}(f)$ represents a smart mathematical manipulation of signals; it does not represent any new physical frequency of the signal. $\mathrm{E}_{pls}(\nu,\tau)$ is just the pulse response function for a given pulse with a single carrier frequency, set by the source oscillator. Thus, we have learned that we should remain alert that spectrometers disperse real carrier frequency of the incident pulse, but with a finite characteristic spatial width, which is a pulse-response function, containing the same carrier frequency information. This is why our derivation of the pulse response function of a spectrometer is very important in understanding the physics of spectrometry and assigning the right spectral width to any pulsed light. If the Time-Frequency Fourier Transform were a principle of nature, then we never have to carry out any spectrometric measurement of pulsed light! Just carry out the pulse-width measurement by a fast detector, or other existing techniques, and then ask the computer to Fourier transform the pulse shape.

Note that even if we use a super stabilized and a single frequency CW laser, the grating will still generate the classical CW *response function* $\mathrm{E}_{cw}(\nu,\tau)$ (shown in the right end of the Eq.11) with a finite "instrumental line width" due to the finite width of the diffraction fringe generated by the superposition effect on the detector determined by the finite "N" number of diffracted beams out of the grating. Therefore, to extract the actual spectral line shape for any real spectrum, this $\mathrm{E}_{cw}(\nu,\tau)$ function must be de-convolved to determine the actual spectral distribution generated by the original source. This part is well known in spectrometry. However, when we send a single pulse Δt with a single carrier frequency, but narrower than $\Delta t \ll \tau_0 (= N\tau)$, the *pulse response function* of Eq.9 becomes broader than the CW response function of Eq.11 because all the N-pulses out of the grating are never stimulating the signal-receiving detector at the same time. The effective "N" becomes less. So, the structure of the fringe is broader; not because any new frequencies are generated by the optical grating with linear response characteristic. It is an instrumental artifact of the tine-decaying amplitude. Therefore, for proper determination of the physical frequency content for a short pulse, we separately need to determine the pulse shape [35] to compute the pulse response function given by Eq.9. In other words, a pulse $a(t)$ with a single carrier frequency ν_0 passing through a grating spectrometer, does not generate any new Fourier frequency $\tilde{a}(f)$ even though apparent spectral fringe gets broader and broader as the pulse gets shorter and shorter..

Newton's law of gravity, Huygens' postulate of secondary wavelet, etc., all constitute real physical actions executed by natural entities. In contrast, mathematical Fourier theorem can be constructed using any pair of well-behaved functions belonging to two different mathematical spaces. It does not even have to belong to real physical space where nature executes all the phenomena. Specifically, for the Time-Frequency Fourier Theorem (TF-FT), neither the time-space, nor the frequency-space are physical spaces. In contrast, atoms generate the EM waves on the ether-tension field, while oscillating in the real 3D space, executing the physical dipolar oscillations, as per Maxwell and Hertz theories. Yet, FT is a very useful and powerful mathematical tool, and we need to use that carefully. In contrast, the space-space Fourier transform that we use to quantify the far-field diffraction pattern, is taking place between two physical planes in the same real space and the diffraction phenomenon is a well-verified postulate by Huygens.

Michelson's Nobel Prize winning invention of the Fourier Transform Spectroscopy (FTS) is another success story of using FTS technique. First, he mathematically defined the innovative "Visibility Function" (autocorrelation function) out of the measured two-beam cosine fringes containing the product of two (conjugate) variable, ν and τ (relative delay between the two mirrors) in generating the superposition intensity fringe, cos(2πντ), and developed the mathematical technique of recovering the spread real frequency ν by measuring the variable τ using his two-beam interferometry. However, Michelson, while applying his FTS technique to measure the Doppler frequency contents in the discharge-lamps of Na, Cd, etc., did not consider the effect of finite pulse width. We are analyzing his data to find out whether the finite time duration of the spontaneous emissions has any significant effect [35, 38].

For imaging instruments, Rayleigh defined the optical resolution out of the diffracted instrumental response function that is inherent in all optical imaging devices. The spatial impulse response function of optical imaging devices has a finite Airy response function, which is the spatial Fourier transform of the aperture function of the imaging device. For engineering convenience, Rayleigh defined the first zero of the Airy function as the resolution "limit". The Huygens-Fresnel diffraction integral, when applied to optical imaging devices like a microscope, one can find that the impulse response (or, point spread function) is the Fourier Transform of the aperture function of the imaging device. If an object aperture is in the X-plane and the imaging aperture is in the Y-plane, then the resolution criterion can be expressed as $\Delta x \Delta y \geq 1$. However, this is only an inconvenience presented by the recorded data. Since the impulse function can be derived analytically, one can always de-convolve the impulse function using a computer and recover extremely high-resolution images. Nature does not have a fundamental uncertainty principle; but our measurement instruments always pose some limits [39], which are recoverable in many situations.

The key take-away from this section is that data generated by the superposition of two or more signals must be physically real and simultaneously acting on an appropriately responsive detector. Some people refer to this as "Locality Principle" of Einstein. Therefore, a superposition equation without incorporating the detector's interaction property (response parameter) does not represent nature's Superposition Principle. Further, a single photon as an elementary particle, or an "indivisible light quanta", cannot carry multiple time and space varying parameters, which are built into the very mathematical definition of all superposition equations.

In the section below, we extend the above understanding to dispel the belief in the quantum mechanically mysterious "single photon, double slit interference".

3.2. Appreciating the reality of a double-slit pattern by exploring a N=2-slit grating.

In this section, we want to underscore the physical reality of the two signals emerging out of any two-slit diffraction device. In the quantum world, some people tend to bring mysticism in the generation of cosine fringes by explaining that it is the distribution in the arrival of the individual photons, which generate the fringe pattern. Such models ignore that Huygens-Fresnel diffraction integral is at the very foundation of the development of classical optical science and engineering [13, 14, 40]. Let us assume we are using a single mode CW laser beam. Then, we can copy the right-hand segment of Eq.11 and using N=2, we get the two-slit diffraction pattern, as in Eq.13, while using some elementary trigonometric identities. We are obtaining the N=2 slit pattern from the general expression for N-slit grating to underscore the physical reality of the two signals propagating through the two slits and then arriving on the detector array having an interaction parameter χ. Here, as for the grating, τ is the relative path delay in the arrival locations of the two signals on the detector plane out of the two slits (Fig.7). Note that we have preserved the classical approach of normalizing and equalizing the incident amplitudes passing through the two slits by maintaining the factor (1/2) in the Eq.13, as is the custom for the N-slit grating. It is different from normalizing the two amplitudes terms by dividing with $\sqrt{2}$ to assure that the square modulus of the superposition equation yields "one photon". In Maxwellian EM waves, there are diffractive light-amplitude pulses, no energy-bullet-photons.

$$ {}_{2Slt.}\mathrm{E}_{cw}(\nu,\tau) = \frac{\chi^2}{2^2}\frac{\sin^2 2\pi\nu\tau}{\sin^2 \pi\nu\tau} = \frac{\chi^2}{2}(1+\cos 2\pi\nu\tau) \tag{13} $$

3.3. Appreciating the reality of a double-slit pattern by direct derivation.

We now re-derive the 2-slit pattern in the traditional way to underscore the physical reality of the diffraction patterns due to each one of the two slits. In N-slit gratings, we usually focus on a specific order of diffraction, usually the 1st, and the effect of the common (all identical) single-slit diffraction pattern is only an intensity reduction curve. However, for the traditional 2-slit diffraction pattern, we record many orders of cosine fringes in both directions from the central zero order fringe. This double-slit fringe pattern gets multiplied by the single slit $(\mathrm{sinc})^2$ diffraction curve (Fig.7). Here, $2a$ is the slit width and $2b$ is the slit spacing. [This slit width $2a$ should not be confused with the variable pulse width $a(t)$]. The screen and the detector array are set at the two focal planes to achieve the far-field condition and avoid recording complex, near field, Fresnel fringes. Eq.14 gives the amplitude flux stimulating the detector array, where $\pm(bx/\lambda f)$ represent the path delays of the two plane waves relative to the centrally symmetric data-recording X-axis. [41, 42]. As underscored amply before, Eq.14, without the detector's interaction parameter $\chi_1(\nu)$, represents the mathematical Superposition Principle. The corresponding Superposition Effect, generated through the square modulus operation by the

$$ i_{cw}(x) = \chi_1(\nu).2a\mathrm{sinc}(2\pi ax/\lambda f)[e^{i2\pi bx/\lambda f} + e^{-i2\pi bx/\lambda f}] \tag{14} $$

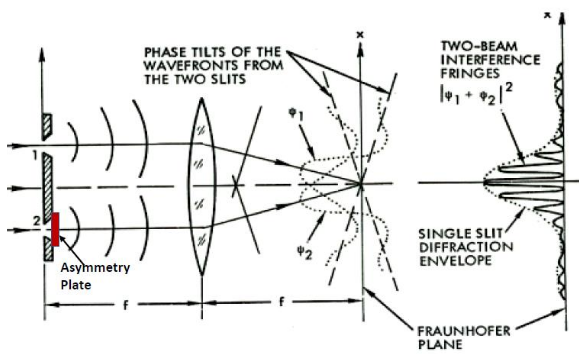


Figure 7. Geometric sketch for a double-slit diffraction pattern. The "almost-identical" two single-slit generates a common sinc-squared diffraction envelope, which multiplies the double-slit cosine-squared pattern. By introducing various asymmetries on one of the two slits, one can experimentally validate the realities of the two signals passing through each of them separately [for details see 42].

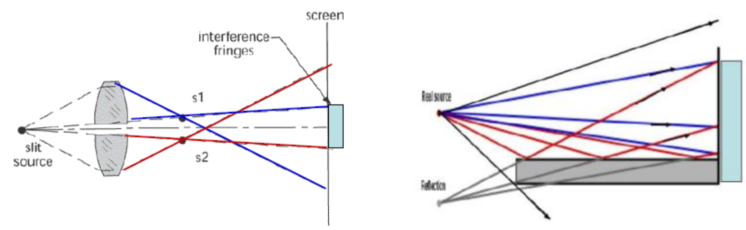
detector, can be given by Eq.15. One can now introduce *asymmetry* between the two slits to appreciate that there are two physical signals diffracting through the two slits.

$$ I(x) = B_1^2\chi_1^2(\nu)\mathrm{sinc}^2(\Lambda ax)\left[1+\cos(2\Lambda bx)\right];\, B_1^2 \equiv 8a^2 \;\&\; \Lambda \equiv\; 2\pi/\lambda f \tag{15} $$

Note that, in the above equation, the spatial differential delays Λbx and Λax can be replaced by the temporal time delay τ to bring similarity with the earlier superposition equations.

Mathematically the slit-plane and the recording-plane represent a pair of conjugate Fourier transform planes with reciprocal relationships between the slit-plane-function and the recorded patterns. Therefore, one can insert various asymmetry-plates, like amplitude, phase and polarization in the slit-plane, and observe the corresponding *reciprocal* changes in the recorded 2-slit fringes. Thus, one can experimentally validate from the characteristic changes in the intensity-fringes and their spatial location, as to which slit has introduced the differential relative changes in the outgoing amplitudes [for details, see ref. 42]. The formation of the 2-slit fringes does not depend upon our "absence of knowledge" as to which slit the signals ("photons") are passing through. Of course, we cannot identify individual photons. First, they do not exist as individual energy-bullets. Second, we do not have any technology to keep track of individual photons. Further, their detection can happen only after destructively absorbing it by a detector.

The physical reality of the two signals from the two-slits were well understood starting from Young's original experiment of 1802, and their later emulation by innovative designs of the experiments by Billet, using a "split lens" and by Lloyd, using a single mirror with inclined illumination. These innovations were necessary because of the difficulty of generating phase-steady signals from two spatially separate slits using thermal light sources. This was very long before we invented lasers. Fig.8 shows the sketches. The key point to note that even though both the superposed wave fronts form a phase steady pair of wave fronts, the simulated two-slit cosine fringes can be observed only within the region where the two wave fronts physically overlap. There would be no fringes outside the region of the *physical overlap* of the two beams.



(a) Double-slit by Billet's Split-Lens (b) "Double slit" by Lloyd's Mirror

Figure 8. Alternate modes of demonstrating double-slit patterns. The fringes are generated only where the two phase-steady signals physically overlap (thin & vertical rectangles at the fringe planes). The postulate of "arrival-distribution of indivisible photons" is not a causal explanation. [Web images modified by the authors.]

3.4. Entanglement and Bell's Theorem.

The word "Entanglement" was formally introduced by Schrodinger in the same year (1935) [43] in response to the critical EPR-paper (Einstein, Podolsky & Rosen) [44]. Einstein's viewpoint was that QM is statistical, just as classical physics of Thermodynamics is and the Boltzmann's population density distribution with temperature is. We also now know Gödel's Incompleteness Theorem [45], which underscores that all theories are necessarily incomplete as they are constructed using unprovable axioms, or postulates, framed using incomplete knowledge of the universe. However, in our viewpoint, Schrodinger's commentary was dominantly in support of his well-established theory, but partly as a "tongue-in-cheek" sarcasm. One can appreciate this from the comments in Fig.9. Schrodinger's conceptual box does not even represent a comprehensive quantum system. Only the radioactive box represents a quantum mechanical emission *process*. All other actions are observable classical *processes* if they are not enclosed inside an opaque box.

Our key point throughout this paper has been to underscore that the purpose of physics theories is to explore and understand nature's physical interaction processes being executed behind all specific interactions (or, phenomena). Have we invented any technological *processes* to generate and manipulate the "Cat-Amplitude"? Can we then carry out the normalization procedure on the two "Cat-Amplitude States", while conceptually connecting all the process steps as a single quantum mechanically valid system [highlighted in Fig.9]?

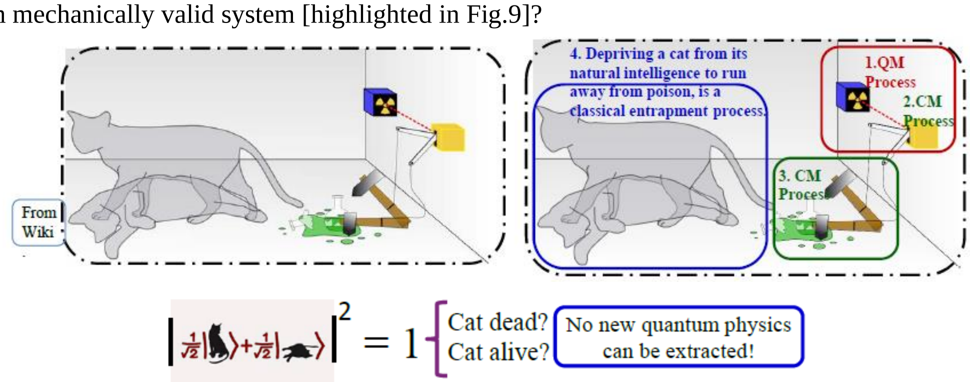


Figure 9. Does Schrodinger's logic of discerning whether a "cat is dead or alive" corroborate a self-consistent quantum phenomenon? There are four functional steps identified above, of which only the first one, the radioactive decay of some radioactive material represents a quantum process. Actions designated as "2" and "3" are purely classical mechanics, the physical processes behind these two steps cannot be explained under the framework of QM. Regarding the step "4", deciding the fate of the entrapped cat must be carried out by a human mind after opening the box; neither of these two actions can be explained using our current knowledge of QM theory.[Original sketches are from the web, but modified by the authors.]

This brings us to Bell's Theorem of statistical Inequality where the amplitude normalization is a critical step to obtain the *number one* after the square modulus operation. Consider the mathematical double-slit diffraction amplitudes in Eq.14. It is a product of the single-slit diffracted amplitude envelope, produced by two identical slits, which is multiplied by the sum of the relative phase delays due to their spatial separation on the slit-plane. It is also multiplied by the amplitude-interaction parameter $\chi_1(\nu)$ for the specific detector being used. For linear quantum detectors, the nonlinear higher order $\chi_n(\nu)$ are normally neglected as they are usually very small. Mathematical and causal logic do not allow us to normalize such an equation by arbitrarily dividing both "amplitudes" with $\sqrt{2}$ to obtain the final "one" to represent the measured outcome as a single photon. Can a single indivisible photon-energy-bullet carry all the physical parametric information from the source- plain to the detection plane, without even having the knowledge of the very detector that generates the ultimate data? We also cannot measure the amplitude of visible light. We do not even have an energy-meter to decisively measure the presence of a single visible photon with energy $h\nu \sim 10^{-18}$ Joules. We have already explained in Section 2 that photoelectron current pulses (PCP), which we count, do not directly represent a single indivisible photon. The scattering losses in the modern optical components exceed 10^{-18} Joules! Our concern is that the mathematically correct Bell's Theorem may not really be applicable to optical two-slit or two-beam Mach-Zehnder interferometers [42].

3.5. Can we apply quantum logic from Schrodinger's equation to classical Maxwellian waves?

The only similarity between Maxwell's and Schrodinger's equations is that both are mathematically second order linear differential equations. Therefore, both separately accept the linear combination of all their *respective* allowed solutions.

$$\text{Schrodinger}: \ \frac{\partial \psi(x,t)}{\partial t} = \frac{i\hbar}{2m}\frac{\partial^2 \psi(x,t)}{\partial x^2} + \frac{1}{i\hbar}V(x,t)\psi(x,t) \tag{16}$$

$$\text{Maxwell:} \ \frac{\partial^2 \psi(x,t)}{\partial t^2} = \frac{1}{\varepsilon\mu}\frac{\partial^2 \psi(x,t)}{\partial x^2} \equiv c^2 \frac{\partial^2 \psi(x,t)}{\partial x^2} \tag{17}$$

This mathematical similarity should not be intermingled [21]. Stable and individual QM particles keep evolving as the same original particle. Only its internal oscillatory energy states can keep evolving due to the potential $V(x,t)$ it experiences, albeit with discrete allowed "quantum" values for the associated energies. Schrodinger's particles obey Newton's first law of *inertia* and require Newton's gravity, Lorentz force, etc., to achieve spatial motion. In contrast, the solutions of Maxwell's equation, the EM waves, do not obey Newton's first law of inertia. Once generated by an atom or a molecule, the Maxwellian wave packets keep moving *spontaneously*, while *spreading out diffractively* with a *fixed velocity* $c^2 = 1/\varepsilon\mu$ within any homogeneous medium, where ε and μ represent dielectric permittivity and magnetic permeability, respectively, of the medium. The intrinsic electric tension ε^{-1} and magnetic resistance μ of the various media provide this perpetual velocity [46]. Einstein initiated century-long attempts to unify physics theories has not yet succeeded despite his derivation of the equivalence of mass-energy using the velocity of light: $m = E/c^2 = E\varepsilon\mu$.

To preserve the integrity of the successful and built-in mathematical logics of the two equations for the two different fields, we should refrain from imposing conditions logically suitable for a solution of one of the fields into the other one, before we succeed integrating the theories harmoniously without introducing any conceptual contradictions. We have not been successful using QED equations to design spectrometers, which is one of the key precision instruments that gave birth to the very quantum-concept due to Planck's invention of the Blackbody Radiation formula. Planck trusted the validity of the Blackbody spectral data, which were measured by using various classical grating spectrometers and classical detectors like bolometers. Modern quantum photodetectors were not in the market in those days.

4. SUMMARY

We started with the ambitious statement, "Resolving Wave-Particle Duality (WPD) could accelerate the mass production of Quantum Computers". However, in the process of resolving WPD we find that we may not be able to generate quantum logic using the dream of "single photon interference", while investigating the interaction process behind the data generation. Therefore, we should be looking for alternate approaches. If quantumness must be the driving factor, then our suggestion is to enhance funding for projects on exploiting the quantum chemistry of biological DNA molecules. They are physically entangled by the quantum-chemical bonding strengths of different molecules and atoms [47, 48]. Measured stimulation of one bond would trigger multiple stimulations in most of the other nearby bonds, which may be read out quantitatively. The powers of computing and intelligence of DNA molecules have been evolving for more than 3.5 billion years. This is the ultimate natural path we should keep trying to exploit more vigorously.

We believe we have presented a logically self-consistent resolution of WPD by proposing that quantum photon, after emission, diffractively propagates as an exponential pulse. This pulse model can explain the emergence of observed statistics generated by the photoelectron current pulses (PCP), which we observe. We have also underscored that we should not assume PCPs as photons. PCPs are the after-effects, through complex amplification processes, of the initial classical-light and quantum-matter *interaction process* guided by dipolar interaction parameter χ_1. A mathematical equation for the Superposition Principle cannot yield the measurable Superposition Effect until we use a detector to generate the data; and all detectors possess some unique light-matter interaction parameter as its multiplying factor. Then the causal mathematical equation does not allow us to arbitrarily normalize the equation for the amplitude-superposition statement to yield the desired "1" count of "indivisible light quanta".

We have also analytically justified the exponential-pulse model for photon by showing that the pulse-response function for the grating spectrometers show that spontaneous emission pulses do corroborate that the observed spectral line width of spontaneous emission is Lorentzian, which is the Fourier transform of an exponential pulse, a well-measured fact. We also have given analytical argument that "photon", being a solution of the Maxwell's classical wave equation, cannot be arbitrarily assumed to obey the superposition properties, which could be separately valid for the solution of the Schrodinger's equation.

5. PROGNOSIS

Finally, we like to comment that we need to revive physics-thinking, which matured during the entire period of 1800, although, triggered by Galileo and Newton during the 1600s. During these periods, the focus was on visualizing the invisible *interaction processes* which nature is using to make the perpetual evolution constantly advancing following perfect *causality*. Newton kept grappling till the end of his life that his law of Gravity cannot be an "action at a distance". It is still not fully resolved [46]. We may define these old fashion approaches to understand nature as the Interaction Process Mapping Thinking (IPM-T). However, from 1905 onwards, we have steadily veered dominantly towards, first, construct the mathematical theories, then design the instruments tailored specifically to validate the predicted data, while giving much less attention to understand and visualize the actual physical processes that are taking place in nature. Thus, our interpretations can be diverse, or changing, as they are not anchored to the actual reality of nature. However, physics is still advancing whenever mathematical logic partially coincides with those of nature. Wigner underscored this staggering power of mathematics [49] even though we do not fully understand the implications of the mathematical parameters [50]. We call this Measurable Data Modeling Thinking (MDM-T).

Maxwell's Electrodynamics evolved out of a century-long IPM-T approach. That is why, despite its incompleteness, it has not suffered from consistent controversies of its interpretations. In contrast, despite staggering successes, QM, as a product of MDM-T, is consistently suffering from controversies in its interpretations. The best way to redirect physics thinking is to bring back IPM-T. We need to leverage the flexible but built-in logic of mathematical equations to facilitate the visualization of the interaction processes that are taking place in nature in every phenomenon. Founders of QM formalism correctly understood that the measurements-validated math cannot directly provide this information. But that does not mean that the creative human minds should remain subservient to this bottleneck as the forever insurmountable one and nature must be accepted as inaccessible but full of abstract mathematical beauty and harmony.

We should appreciate that mathematical logics, already built into the *mathematical operators* ("+", "-", $\partial / \partial x$, $\partial^2 / \partial t^2$, etc., etc.) represent nature's physical actions on the, or by the parameters, represented by the *algebraic* *symbols* straddling these *operators*. This is how we have been building our mathematical equations to represent nature's actions for centuries past. We should keep iteratively applying this old fashioned IPM-T on the measured data that validates a particular equation. To visualize the invisible interaction processes, we should use the built-in *causality* in the equation to guide our imaginations and visualize the implied operation (interaction process) by the mathematical operators connecting the algebraic symbols (properties of the interactants). If a mathematical equation works, we should accept the built-in causal relationships between the different symbols and operators. Then leverage the guidance to understand and visualize the physical processes behind the phenomenon. If we are summing two physical signals with multiple variables, we should not assume that a single indivisible "photon" or "electron" can carry all the variable physical parameters and generate the superposition effect on to the detection plane without incorporating the detector's interaction parameter (see Eq.14). When an equation fails to explain the "hidden" interaction processes, we should take it as a que to explore more advanced thinking and reformulate the theory. Compare the two equations for the photoelectric effect presented in Eq.2. The right-hand equation is due to Einstein. It is a correct energy-balancing equation. However, the left-hand equation is phenomenologically better as it models the initial light-matter, amplitude-amplitude interaction process, which eventually releases the quantum mechanically bound electron.

We believe that the three Nobel laureates of 2023 [51-53] have carried out life-long ventures into exploring intra-atomic behavior by using the ultrashort laser pulses, well beyond the limits set by Heisenberg's "Uncertainty Principle" [39]. We believe this is the old fashioned IPM-T approach and we have also tried to apply this approach in this paper – (i) model and visualize the interaction processes behind the emergence of photoelectrons, and (ii) the emergence of data pertaining to the superposition of multiple physically real signals. We found that it is difficult to extract Quantum Entanglement properties out of the physical superposition data, which are generated through *local* interaction between light and quantum detector [42].

Why should we emphasize modeling interaction processes that we cannot directly extract out of measurements?

We can invent and make things work only by emulating the rules allowed by nature. The entire cosmic evolution is a creative system engineering marvel. All the biological species, from single-celled to multicellular species, survive, thrive and evolve, because of their body's biological engineering intelligence that guides them to survive. However, to enhance their living conditions, they also invent and innovate external engineering tools to change their environment as needed. Humans, with the unusually rapid development of these invention skills, are now in the process of de-stabilizing the biosphere by ushering in Global Warming, a few billion years ahead of Solar Warming (because of the inevitable demise of the Sun). As a conscientious species, we need to become better engineers by adopting IPM-T, over and above the prevailing trend of MDM-T. Then we can buy time to find other habitable planets.

Biological evolution has been going on for at least 3.5 billion years on our earth leveraging molecular Quantum Chemical Engineering of molecules and the Classical Physics of Materials Engineering in different shapes and forms. From single-celled to multicellular species – all are doing this to claim their nieces and keep evolving successfully. Hence, we must consciously and proactively appreciate the primacy of the Evolution Process Congruent Thinking (EPC-T) in every field of human endeavors - arts, science and engineering - to guide our evolution and remain congruent with the causal engineering processes of nature. It is, of course, easier for the fields of Physics and Engineering, because we use cause-effect relating mathematics to remain precise in validating the rules of nature. Below are two examples, which underscore the primacy of engineering thinking, one taken from the deep past and the other from the recent past, which relate to Quantum Physics.

Let us recall the invention of generating fire-on-demand by our forefathers some quarter million years ago [55]. They were under the persistent pressures (i) to drive away the large predator animals, (ii) to cook food for faster assimilation of energy and (iii) to have more time to plan, think and enjoy life. By trial-and-error different tribes eventually perfected a couple of methods to generate *fire on demand*. That was the first revolutionary step in human evolution, which happened at least a quarter million years ago, when we did not even have a proper language, forget about mathematical theory. Today we can buy a refined version of the same tool for $1 as a lighter! Our forefathers had no idea of the physics behind the generation of sparks by striking two stones. It is a quantum mechanical process of ionization of the Silica molecules by transferring biological muscle-energy, followed by the re-neutralization of the atoms by the available free electrons in the surrounding space, which cascade down from outer quantum energy levels to the lower ones. These quantum cascading of electrons trigger the emission of infrared to visible light. We started understanding some physics of ionization only during the late 1800's with the invention of discharge tubes.

Another revolution of leveraging QM took place in the 1990's when we perfected the global fiberoptic communication system and the internet. This system has already converted the diverse world of 193 countries into a one single interconnected Global Village through international commerce. To achieve this engineering feat, we mastered the four necessary basic engineering functions, (i) Generation, (ii) Modulation, (iii) Propagation, and (iv) Detection of electrons and photons. However, we still do not fully understand what "electrons" are and what "photons" are! We can keep inventing novel instruments whenever the working principles are allowed by the rules of nature, irrespective of whether we have succeeded in developing a *complete* theory. However, a complete theory can help us invent a diversity of novel instruments.

There is a strong need to undertake efforts to master the physical *engineering processes* behind the emergence of diverse kinds of quantum superposition effects. This is dictated by the interaction processes between the superposed signals and the quantum detector. This interaction process itself is a phenomenon of nature, dictated by the interaction properties of the detectors. We can then emulate those *engineering processes* and accelerate the manufacturing of Quantum Computers to execute quantum algorithms.

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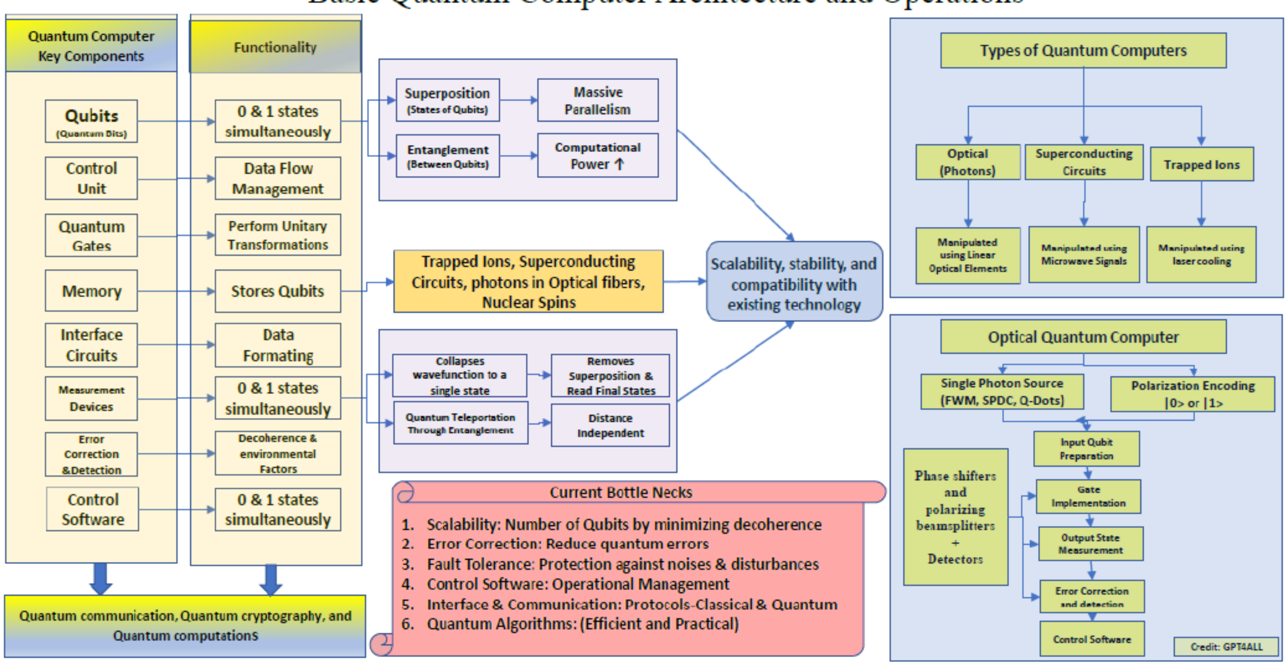
APPENDIX-A

The State of Q-Computer Technology
(Credit: **GPT4ALL**)

Basic Quantum Computer Architecture and Operations



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