New Experiments Call for a Continuous Absorption Alternative to Quantum Mechanics – The Unquantum Effect

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A famous beam-split coincidence test of the photon model was performed with γ-rays instead of visible light. A similar test was performed to split α-rays. In both tests, coincidence rates greatly exceed chance, leading to an *unquantum* effect. In contradiction to quantum theory and the photon model, these new results are strong evidence of the long abandoned accumulation hypothesis, also known as the loading theory. Attention is drawn to assumptions applied to past key experiments that led to quantum mechanics. The history of the loading theory is outlined, and a few key experiment equations are derived, now free of wave-particle duality. Quantum theory usually works because there is a subtle difference between quantized and thresholded absorption.

1 Introduction

Since Einstein's photoelectric work of 1905, quantum mechanics (QM) has endured despite its bizarre implications because no strong experimental evidence has been put forth to refute it. Such new evidence is presented in detail here.

By QM and the photon model, a singly emitted photon of energy $h\nu_L$ must not trigger two coincident detections in a beam-split coincidence test (see p. 50 in [1] and p. 39 in [2]) where h is Planck's constant of action, and ν_L is frequency of the electromagnetic wave. Beam-split coincidence tests of past have seemingly confirmed QM by measuring only an accidental chance coincidence rate [3–6].

Here, new beam-split coincidence experiments use γ-rays instead of visible light. The detectors employed have high "energy" resolution, whereby their pulse-height is proportional to ν_L. The γ-ray detection-pulses were within a full-height window, indicating we are not dealing with frequency down-conversion.

To measure such an *unquantum* effect implies that a fraction of pre-loaded energy was present in the detector molecules preceding the event of an incoming classical pulse of radiant energy. It is called the *accumulation hypothesis* or the *loading theory* [7–12] (see p. 47 in [12]). The pre-loaded energy came from previous absorption that did not yet fill up to a threshold. The unquantum tests give us a choice: we either give up an always-applicable *particle-energy conservation*, or give up *energy conservation* altogether. We uphold energy conservation.

A beam-split coincidence test compares an expected chance coincidence rate R_c to a measured experimental coincidence rate R_e. Prior tests [3–6] all gave $R_e/R_c = 1$. Past authors admitted that exceeding unity would contradict QM. These unquantum experiments are the only tests known to reveal $R_e/R_c > 1$. This clearly contradicts the one-to-one "Born rule" probability prediction of QM.

It is counterintuitive to attempt to contradict the photon model with what was thought to be the most particle-like form of light, γ-rays. Prior tests have only pitted QM against an overly classical model that did not consider a pre-loaded state. A beam-split coincidence test with γ-rays is fair to both the loading theory and photon theory. The loading theory takes h as a maximum. This idea of action allowed below h is algebraically equivalent to "Planck's second theory" of 1911 [9, 10, 14, 15]. There, Planck took action as a property of matter, not light (see p. 136 in [10]). The unquantum effect implies that it was a false assumption to think h is due to a property of light. The loading theory assumes light is quantized at energy $h\nu_L$ only at the instant of emission, but thereafter spreads classically.

Similar new beam-split tests with α-rays, contradicting QM with $R_e/R_c > 1$, are also described herein. This is important because both matter and light display wave-particle duality, and its resolution requires experiment and theory for both.

2 Gamma-ray beam-split tests

In a test of unambiguous distinction between QM and the loading theory, the detection mechanism must adequately handle both time and energy in a beam-split coincidence test with two detectors, as shown in the following analysis. Surprisingly, discussions of pulse "energy" (height) resolution have not been addressed in past tests [3–6] which were performed with visible light, and one test with x-rays. Referring to Fig. 1 we will analyze a photomultiplier tube (PMT) pulse-height response to monochromatic visible light [16]. A single channel analyzer (SCA) is a filter instrument that outputs a window of pulse heights ΔE_{window} to be measured; LL is lower level and UL is upper level (italic symbols denote notation in figures). If we set LL to less than half E_{mean}, one could argue we favored the loading theory, because a down-conversion might take place that would record coincidences in both detectors. Also, if LL were set too low, one could argue we were recording false coincidences due to noise. If we set LL higher than half E_{mean}, one could argue we were

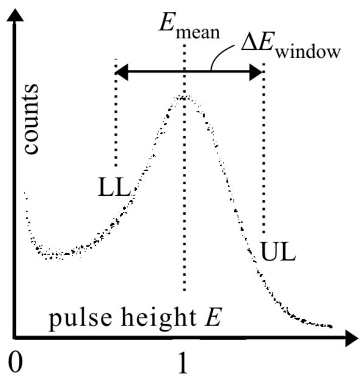

Fig. 1: PMT pulse-height response. Data according to [16].

unfair to the loading theory by eliminating too many pulses that would have caused coincidences. Therefore a fair test requires high pulse-height resolution: $E_{mean} \gg \Delta E_{window}$. This criterion is not possible with a PMT or any visible light detector, but is easily met with γ-rays and scintillation detectors.

A high photoelectric effect detector-efficiency for the chosen γ-ray frequency was judged to enhance the unquantum effect, and this proved true. The single 88 keV γ-ray emitted in spontaneous decay from cadmium-109 (^{109}Cd), and detected with NaI(Tl) scintillators fit this criterion (see p. 717 [17]) and worked well. All radioisotopes used were low-level license-exempt.

A γ test of July 5, 2004 (see Fig. 6 in [18]) will be described in detail, and others briefly. After spontaneous decay by electron capture, ^{109}Cd becomes stable ^{109}Ag. ^{109}Cd also emits an x-ray, far below *LL*. We know that only one γ is emitted at a time, from a coincidence test with the γ source placed between two facing detectors that cover close to 4π solid angle (see p. 693 [19]). That test only revealed the chance rate, measured by

$$R_c = R_1 R_2 \tau \,, \tag{1}$$

where R_1 and R_2 are the singles rates from each detector, and τ is the chosen time window within which coincident events are counted.

The test was performed with two detectors like those shown in Fig. 2, each being an NaI(Tl) crystal coupled to a PMT. The ^{109}Cd source was inside a tin collimator placed directly in front of detector #1, a custom made 4 mm thick 40 × 40 mm crystal. Directly behind detector #1 was detector #2, a 1.5″ Bicron NaI-PMT. We call this thin-and-thick detector arrangement tandem geometry. This test was performed inside a lead shield [20] that lowered the background rate 1/31. Referring to Fig. 3, components for each of the two detector channels are an Ortec 460 shaping amplifier, an Ortec 551 SCA, and an HP 5334 counter. For each detector channel, singles rates R_1 and R_2 were measured by calculating (counter pulses)/(test duration). A four channel Lecroy LT344 digital

Fig. 2: Two γ-ray detectors in tandem geometry; a demonstrator unit. Detector #1 was used with other components for data shown.

storage oscilloscope (DSO) with histogram software, monitored the analog pulses from each shaping amplifier on *Ch*1 (channel 1) and *Ch*2, and from the timing pulse outputs from each SCA on *Ch*3 and *Ch*4. Stored images of each triggered analog pulse assured that the number of misshaped pulses was well below 1%. Misshaped pulses can occur from pulse overlap and cosmic rays. This DSO can update pulse-height E and time difference Δt histograms after each triggered sweep. To assure exceeding particle-energy conservation, *LL* on each SCA window was set to $\sim 2/3$ of the ^{109}Cd γ characteristic pulse-height.

Data for this test is mostly from Fig. 4, a screen capture from the DSO. A control test with no source present is Δt histogram trace B of 16 counts/40.1 ks = 0.0004/s, a background rate to be subtracted. With τ taken as 185 ns, the chance rate from Eq. 1 was (291/s)(30/s)(185 ns) = R_c = 0.0016/s. From trace A and numbers on Fig. 4, R_e = 295/5.5 ks − 0.0004/s = 0.053/s. The unquantum effect was R_e/R_c = 33.5 times greater than chance. The described test is not some special case. Much critical scrutiny [18, 20] was taken to eliminate possible sources of artifact, including: faulty instruments, contamination by ^{113}Cd in the ^{109}Cd, fluorescence effects, cosmic rays, possibility of discovering stimulated emission, pile-up errors, and PMT artifacts. Hundreds of similar tests and repeats of various form have successfully defied QM. These tests include those with different sources (^{57}Co, ^{241}Am, pair-annihilation γ from ^{22}Na [21], ^{54}Mn, ^{137}Cs) and different detectors (NaI, high purity germanium, bismuth germinate, CsI), different geometries, and different collimator materials.

^{109}Cd was prepared in two chemical states of matter (see Fig. 11 in [18]). A salt state was prepared by evaporating an isotope solution. A metal state was prepared by electroplating the isotope in solution onto the end of a platinum wire. The unquantum effect from the salt state was 5 times greater than

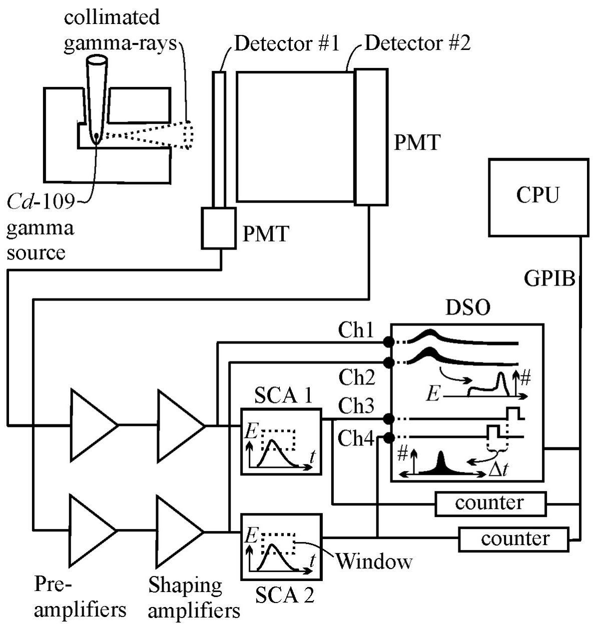

Fig. 3: γ-ray coincidence experiment.

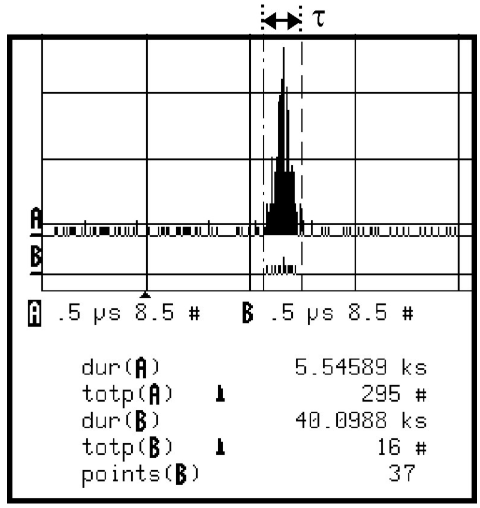

Fig. 4: γ-ray Δt from DSO.

from the metal state. This discovery measures how chemistry affects nuclear electron capture in isotope decay. We theorize that γ from the salt-crystaline source are more coherent and that the unquantum effect is enhanced by coherent waves. The singles spectrum did not measurably change with this chemical state change, so this sensitivity is due to the unquantum effect. A similar effect was reported [22] but was not nearly as sensitive or simple.

The unquantum effect is sensitive to distance (see Fig. 8–9 in [18]). A longer γ wavelength from ^{241}Am shows an enhanced unquantum effect when placed closer to the detectors, while a shorter γ wavelength from ^{137}Cs shows an enhanced effect when placed farther from the detector. Therefore, we can see how the spreading cone of a classical γ defines an area that matches the size of the microscopic scatterer (electron). We can measure how the short spatial and temporal qualities of a classical spreading γ wave-packet trigger the unquantum effect.

In addition to tandem geometry, a beam-split geometry was explored successfully. Different materials were tested to split an energy-fraction of a classical γ to one side, while the remaining ray passed through (see Fig. 12 in [18]). This beam-split geometry was developed into a spectroscopy whereby the pulse-height spectrum of the second detector was expanded. A non-shifted spectrum-peak indicates elastic Rayleigh scattering. A shifted spectrum-peak indicates non-elastic Compton scattering.

In beam-split geometry, crystals of silicon and germanium were explored with an apertured γ path to obtain angle resolution (see Fig. 13 in [18]). The unquantum effect varied with crystal orientation to reveal a new form of crystallography. This was not Bragg reflection from atomic planes, but rather from periodicity smaller than inter-atomic distance, perhaps electron-orbital structure.

The unquantum effect is sensitive to temperature of the beam-splitter (see Fig. 18 in [18]). A liquid nitrogen cooled slab of aluminum delivered a 50% greater unquantum effect, as expected.

Magnetic effects were explored with coincident deflected pulse-height analysis (see Fig. 14–16 in [18]) in beam-split geometry. A ferrite scatterer in a magnetic gap revealed enhanced Rayleigh scattering, indicating a stiff scatterer, as one would expect. A diamagnetic scatterer in a magnetic gap revealed enhanced Compton scattering, indicating a flexible scatterer, as expected.

The unquantum effect's increase/decrease response to several physical variables in the direction that made physical sense solidifies its fundamental validity. Each of the above mentioned modes of unquantum measurement represents a useful exciting discovery.

There is a simple way to measure the unquantum effect with a single NaI-PMT detector and a pulse-height analyzer [20]. Measure the ^{109}Cd sum-peak's count rate within a preset ΔE window that is set at twice 88 keV, and compare to chance. The result approached chance $\times 2$.

Our most impressive γ-split test [21] used ^{22}Na emitting a positron that annihilates into two 511 keV γ. The decay also emits a stronger γ that was caught in a third detector. In this triple-coincidence test $R_c = R_1 R_2 R_3 \tau_{12} \tau_{23}$. Only one from each pair of annihilation γ-rays were then captured by two detectors in tandem. Here $R_e/R_c = 963$. Energy $= h\nu$ is still true as a threshold value, but these experiments say there are no photons.

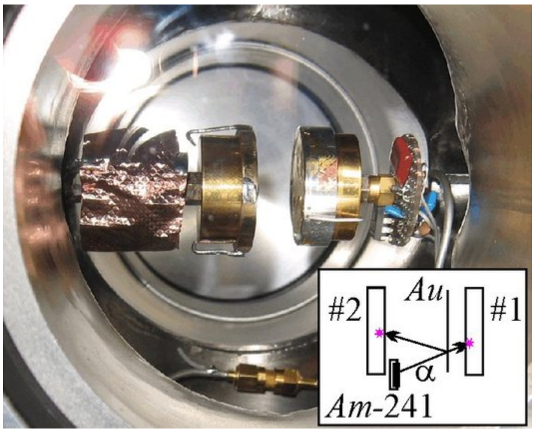

Fig. 5: α-split test in vacuum chamber.

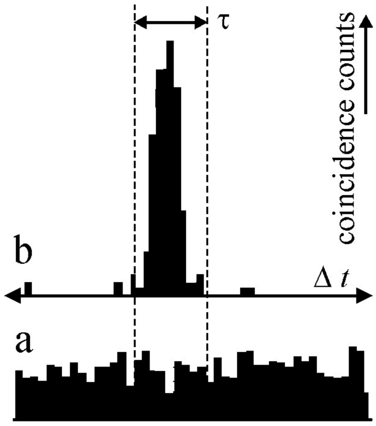

Fig. 6: α-ray Δt plots.

3 Alpha-ray beam-split tests

^{241}Am in spontaneous decay emits a single 5.5 MeV α-ray and a 59.6 keV γ. An α is a helium nucleus. This sounds like a particle, but consider a helium nuclear matter-wave. If the wave was probabilistic, the particle would go one way or another, and coincidence rates would only approximate chance. I performed hundreds of various tests in four vacuum chamber rebuilds. Two silicon Ortec surface barrier detectors with adequate pulse-height resolution were employed in a circuit nearly identical to Fig. 3. Fig. 5 shows the detectors and pre-amplifiers in the vacuum chamber. These tests were performed under computer CPU control by a program written in QUICKBASIC to interact with the DSO through a GPIB interface. Both SCA *LL* settings were at 1/3 of the characteristic α pulse-height, because it was found that an α-split usually maintains particle-energy conservation. The coincidence time-window was τ = 100 ns. The Δt histograms of Fig. 6 were from DSO screen captures.

Data of Fig. 6-a was a two hour control test with the two detectors at right angles to each other and the ^{241}Am centrally located. Only the chance rate was measured, assuring that only one α was emitted at a time. This arrangement is adequate, and 4π solid angle capture is not practical with α. Any sign of a peak is a quick way to see if chance is exceeded. Background tests of up to 48 hours with no source gave a zero coincidence count.

Data of Fig. 6-b (Nov. 13, 2006) was from the arrangement of Fig. 5 using two layers of 24 carat gold leaf over the front of detector #1. Mounted on the rim of detector #2 were ^{241}Am sources, shaded to not affect detector #2. Every analog detector pulse in coincidence was perfectly shaped. $R_c = 9.8{\times}10^{-6}$/s, and $R_e/R_c = 105$ times greater than chance.

From collision experiments, the α requires $\sim$ 7 MeV per nucleon to break into components, and even more for gold [17]. It would take 14 MeV to create two deuterons. The only energy available is from the α's 5.5 MeV kinetic energy. So for any model of nuclear splitting there is not enough energy to cause a conventional nuclear split. Also plotted from the CPU program and data from the test of Fig. 6-b is data re-plotted in Fig. 7. Fig. 7 depicts pulse heights plotted as dots on a two dimensional graph to show coincident pulse heights from both detectors. The transmitted and reflected pulse-height singles spectra were carefully pasted into the figure. We can see that most of the a pulses (dots) are near the half-height marks; α usually splits into two lower kinetic-energy He matter-waves. Six dots, circled, clearly exceeded particle-energy conservation. Counting just these 6, we still exceed chance: R_e/R_c = 3.97. This is a sensational contradiction of QM because it circumvents the argument that a particle-like split, such as splitting into two deuterons, is somehow still at play.

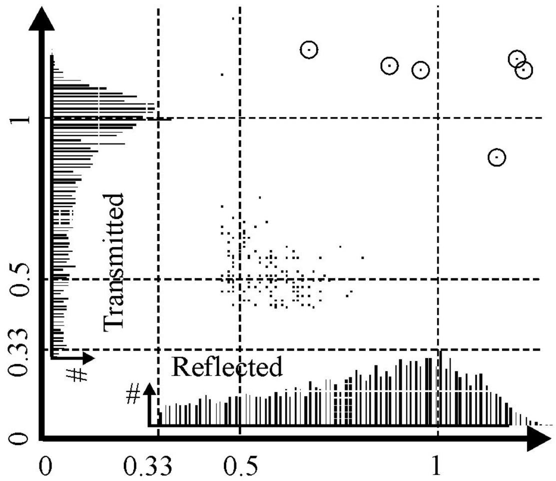

Fig. 7: Coincident α pulse-height pairs,

In search for alternative explanations, we found none and conclude: an α matter-wave can split and continuous absorption can fill a pre-loaded state of He up to a detection threshold. Also, the α-split test demonstrates how the loading theory applies to historical interference and diffraction tests with electrons, neutrons, and atoms [23, 24]. Several other materials were tested in transmission and reflection geometries to reveal the usefulness of this matter-wave unquantum effect in material science [21]. It is not necessary to use gold to exceed chance, but many materials tested just gave chance.

4 History of the loading theory and its misinterpretation

A believable report of such disruptive experimental results requires an accompanying historical and theoretical analysis.

Lenard [7, 8] recognized a pre-loaded state in the photoelectric (PE) effect with his trigger hypothesis. Most physicists ignored this idea in favor of Einstein's light quanta [25] because the PE equation worked. Planck (see Eq. 14 in [9], and p. 161 in [10]) explored a loading theory in a derivation of his black body law that recognized continuous absorption and explosive emission. Sommerfeld and Debye [11] explored an electron speeding up in a spiral around a nucleus during resonant light absorption. Millikan (see p. 253 in [13] described the loading theory, complete with its pre-loaded state in 1947, but assumed that its workings were "terribly difficult to conceive." In the author's extensive search, physics literature thereafter only treats a crippled version of the loading theory with no consideration of a pre-loaded state.

Most physics textbooks (e.g. [26], p. 79) and literature (e.g. [27]) routinely use photoelectric response time as evidence that the loading theory is not workable. Effectively, students are taught to think there is no such thing as a preloaded state. Using a known light intensity, they calculate the time an atom-sized absorber needs to soak up enough energy to emit an electron. One finds a surprisingly long accumulation time (the longest response time). They claim no such long response time is observed, and often quote ~ 1 ns, the shortest response time from the 1928 work of Lawrence and Beams [28] (L&B). Such arguments unfairly compare a shortest experimental response time with a longest calculated response time. An absorber pre-loaded to near threshold explains the shortest response times. The longest response time from L&B was ~ 60 ns. L&B did not report their light intensity, so it is not fair to compare their results to an arbitrary calculation. Energy conservation must be upheld, so an appropriate calculation is to measure the longest response time and the light intensity, assume the loading theory starting from an unloaded state, and calculate the effective size of the loading complex. The loading theory was the first and obvious model considered for our earliest experiments in modern physics. There is no excuse for the misrepresentation outlined here.

5 A workable loading theory

For brevity, the theory is elaborated for the charge matter-wave. If we develop three principles, we will find they explain both the quantum and unquantum experiments [29]:

1. de Broglie's wavelength equation is modified to the wavelength of a beat or standing-wave envelope-function of Ψ;
2. Planck's constant h, electron charge e, and mass constants like the electron mass m_e are maximum thresholds whereby emission is quantized but absorption is continuous and thresholded;
3. Ratios h/e, e/m, h/m, in our equations are conserved as the matter-wave expands and thins-out.

In de Broglie's derivation of his famous wavelength equation (see. p. 3 in [30])

$$\lambda_\Psi = \frac{h}{m_e v_p}, \tag{2}$$

he devised a frequency equation

$$h\nu_\Psi = m_e c^2, \tag{3}$$

and a velocity equation

$$v_p V_\Psi = c^2. \tag{4}$$

For equations (2–4), subscript Ψ is for either a matter-wave or a probabilistic wave, λ_Ψ is the phase wavelength, ν_Ψ the phase frequency, v_p the particle velocity, V_Ψ the phase velocity, and m_e the electron mass. Equations (3) and (4) remain widely accepted, but have serious problems. Equation (3) is only true when using ν_L instead of ν_Ψ to calculate a mass equivalent. If we measure v_p, λ_Ψ, and m_e for matter diffraction, equation (3) fails. Our experimental equations use h associated with kinetic energy, or momentum, not mass-equivalent energy.

As for equation (4), one might attempt to extract it from the Lorentz transformation equation of time by dimensional analysis, but its derivation independent of equations (2) or (3) has not been found by the author. Nevertheless, it describes an infinite V_Ψ in any particle's rest frame. Many physicists use equation (4) to justify the probability interpretation of QM, (see p. 89 in [31]) but this leads to "spooky action at a distance" we are all well aware of.

A much more reasonable frequency equation is the PE effect equation $h\nu_L = {}^1\!/_2\, m_e v_p^2$, with the work function not yet encountered. It is very reasonable to understand that something about charge is oscillating at the frequency of its emitted light, but just how to replace ν_L with a charge frequency requires insight. Recall the Balmer or Rydberg equation of the hydrogen spectrum in terms of frequency in its simplest form: $\nu_L = \nu_{\Psi 2} - \nu_{\Psi 1}$. Here ν_Ψ is frequency of a non-probabilistic Ψ matter-wave. The hydrogen atom is telling us that the relationship between ν_L and ν_Ψ is about difference-frequencies and beats. Consider that this difference-frequency property is fundamental to free charge as well as atomically bound charge. Beats, constructed from superimposing two sine waves are understood from a trigonometric identity to equal an averaged Ψ wave modulated by a modulator wave M, as graphed in Fig. 8. If we take M as the coupling of light to charge we see that there are two beats per modulator wave, and we can write a relationship between light frequency and the frequency of charge beats: $2\nu_{\text{L}} = \nu_g$. Group velocity is commonly substituted for particle velocity, so $v_p = v_g$. Substituting the last two equations into the PE equation makes $h\nu_g = m_e v_g^2$. Groups are periodic, so we apply $\nu_g = v_g/\lambda_g$ to derive a wavelength equation (principle 1):

$$\lambda_g = \frac{h}{m_e v_g}\,. \tag{5}$$

Notice that both the PE equation and equation (5) have h/m_e. Recall several equations applicable to so-called "wave properties of particles": Lorentz force, PE, Compton effect, Aharonov-Bohm effect, others. They all have ratios like e/m, h/m, h/e. Examining $h/m_e \equiv Q_{h/m}$, if action is less than h and mass is less than m_e and the proportion is conserved, we would not be able to tell if those values went below our thresholds (h, m, e) while the charge-wave spreads out and diffracts (principles 2 & 3). Therefore we can write equation (5) as $\lambda_g = Q_{h/m}/v_g$ and the PE equation as $\nu_{\text{L}} = {}^1/_2\, Q_{m/h} v_g{}^2$. At threshold, $m_{group} = m_e$ and at sub-threshold we use Q ratios to emphasize wave nature (Q for quotient). To understand the PE effect without photons, visualize the pre-loaded state in the $Q_{m/h}$ ratio. Energy loads up to threshold and an electron is emitted explosively (principle 2); thereafter, the charge-wave can spread classically.

The Compton effect is often claimed to require QM treatment. A classical treatment is in Compton and Allison's book (see p. 232 in [12]) based upon a Bragg grating of envelopes from standing de Broglie waves. However, the envelopes were weak. If charge structures were inherently composed of beats of length d, it would naturally create a plausible Bragg grating. Use the Bragg diffraction equation $\lambda_{\text{L}} = 2d\sin(\phi/2)$, where ϕ is deflection angle. Substitute for d, λ_g from equation (5). Solve for v_g and insert into the Doppler shift equation $\Delta\lambda_{\text{L}}/\lambda_{\text{L}} = (v_g/c)\sin(\phi/2)$. Simplify using the trigonometric identity $\sin^2\theta = [1-\cos(2\theta)]/2$ and $Q_{h/m}$ to yield

$$\Delta\lambda_{\text{L}} = \frac{Q_{h/m}}{c}(1-\cos(\phi)),$$

the Compton effect equation.

Also related to the Compton effect are popular accounts of the test by Bothe and Geiger. The measured coincidence rate was not a one-to-one particle-like effect as often claimed, but rather the coincidence rate was $\sim 1/11$ [32].

What about quantized charge experiments? Measurements of e are performed upon ensembles of many atoms, such as in the Millikan oil drop experiment, and earlier by J. J. Thompson. Granted, electron detectors go click, but that is the same threshold effect demonstrated by the unquantum α-split experiments. From evidence of charge diffraction alone, it was a poor assumption to think charge was always quantized at e. Charge, capable of spreading out as a wave with a fixed e/m_e ratio for any unit of volume, loading up, and detected at threshold e, would remain consistent with our observations. Furthermore, the electron need not be relatively small. Chemists performing Electron Spin Resonance measurements often model the electron to be as large as a benzene ring. A QM electron would predict a smeared-out ESR spectrum.

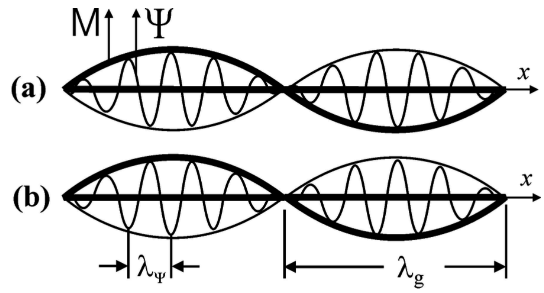

Fig. 8: Illustration of the concept of matter and antimatter. (a) Two positron beats. (b) Two electron beats.

The following is a list of famous experiments and principles re-analyzed with this newly developed Loading Theory (LT) by the author [29]: PE effect, Compton effect, shot noise, black body theory, spin, elementary charge quantization, charge & atom diffraction, uncertainty principle, exclusion principle, Bothe-Geiger experiment, Compton-Simon experiment, and the nature of antimatter, as envisioned in Fig. 8. The LT visualizes these fundamental issues, now free of wave-particle duality.

The LT supported by the unquantum effect easily resolves the enigma of the double-slit experiment. The wave of light or matter would load-up, and show itself as a click at a threshold.

These realizations lead to matter having two states: (1) a contained wave in a particle state, and (2) a spreading matter-wave that is not a particle at all, yet carries the wave-form matching a loading-up particle. One may protest by quoting experiments in support of QM, such as giant molecule diffraction, EPR tests, and quantum cryptography. My analysis of major flaws in such tests, and elaboration of topics outlined here, are freely viewable from my posted essays and at `www.unquantum.net`.

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