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A Theory of Radiation Processes that Adheres Strictly to the Conservation Laws

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Abstract

It is hypothesized that in order for atomic radiating systems to be in strict compliance with the conservation laws their fields must be quantized. A hydrogen atom is conceived of therefore as the dynamic superposition of three field sources: proton, electron, and photon; and the formalism of non-relativistic quantum mechanics is interpreted as stepwise linear solutions to the problem of determining the superposition of their partial differential equations. The electron oscillator is introduced to describe energy conservation in emission and absorption processes; and causality is invoked to account for the non-commutation of observables. The model of light that evolves suggests applications for testing the theory in interference phenomena and astronomy.

1. Introduction

All theories of nature must be in conformance with the conservation of energy since it has never been known to fail. The conservation of momentum, on the other hand, has been limited to testing the validity of more visible high energy phenomena. For example, in studies of nuclear magnetic resonance an angular correlation of successive photons due to recoil momentum was found that is twice the incoherent rate [2]. This leads to the emission of spontaneous coherent radiation in atomic radiating systems. However, the existence of photon correlations has also been confirmed in much lower energy optical and radio wave experiments in the form of temporal coherence [3]. Recoil momentum has not been used to explain photon correlations in these experiments.

The momentum exchange of low energy radiating systems is described in non-relativistic quantum mechanics by a quantum reformulation of the Fourier series representing an electron's position coordinates,

$$\mathbf{pq} - \mathbf{qp} = i\hbar \tag{1}$$

where $\mathbf{p}$ and $\mathbf{q}$ are matrix operators in an infinite complex linear vector space. The use of fields is implicit to this representation so that when momentum is absorbed it is distributed over the entire atom. Similarly emission occurs as a spherical wave with no net momentum transfer. In contrast emission by recoil momentum is both highly localized and directed. It is an unsatisfactory state of the theory that radiation processes are explained in very different ways, i.e. as localized or as diffuse, simply because they occur at distinct energies.

Because a Coulomb potential is used in the Hamiltonian of radiating systems, energy that is absorbed through photon annihilation is also believed to be diffusely and uniformly distributed in the atom in the form of a classical field. A second quantization of the Hamiltonian is necessary to recover the photon in radiation fields.

2. Hypothesis

It is hypothesized that photons are not destroyed by absorption, but instead become localized in bound states; and that second quantizations are in effect quantizations of momentum. This does not mean as in the case of energy quantization that only certain momentum states are allowed, rather it indicates that electromotive forces have a particle-like aspect and can be easily expelled from excited states by means of recoil momentum. This hypothesis may be expanded upon by making several closely related assumptions:

1) The simplest atom, hydrogen, consists of proton, electron, and photon.

2) The photon has an impenetrable core surrounded by one cycle of a sinusoidal electromagnetic wave, with a field strength that falls off as $1/r$.

3) Coulomb's law is invalid for describing the energy states of atoms because the concept of a test charge with infinitesimal influence is untenable.

4) The momentum of a photon is unaffected by interactions of field[1].

5) Momentum exchange only occurs if the core of a photon is involved.

[1]Experiment has shown that photons are not deflected by intense electric or magnetic fields.

3. Momentum conservation

3.1. By Fourier analysis

In quantum theory the rates of absorption and induced emission of radiating systems are calculated separately and found to be equal as a first order approximation [4]. If, on the other hand, recoil momentum is used to account for induced emission then this result follows naturally from the implementation of causality. However, due to the uncertainty principle arguments based on causality are in conflict with non-relativistic quantum mechanics and these differences must be resolved. To see why causality is currently believed to fail it will be necessary to examine the commutation relations from which uncertainty was derived. Following the original discussion of the Kramers-Heisenberg dispersion theory of 1925 in which the non-commutation of observables first appeared, we define a physical variable X, or observable, as a quantum theoretical reformulation of classical Fourier series [5]

$$X = \sum_{\tau} A(n, n-\tau) \exp[2i\pi\nu(n, n-\tau)t], \qquad \tau = \pm 1, \pm 2, ... \tag{2}$$

Where negative τ represents absorption and positive τ represents emission. The question of commutation may be studied in the Kramers dispersion formula by taking the limit of very high incident frequency relative to absorption and emission frequencies and interpreting variables as in (2). When two variables are multiplied together in a different order we find that they do not commute

$$YX - XY \neq 0. \tag{3}$$

To see why recall that the physical variables, or observables, X and Y represent vectors in Hilbert space whose magnitude defines a spectral line intensity, or transition amplitude; and whose direction corresponds to either an absorption (increase in state) or an emission (decrease in state). Therefore, keeping in mind that each vector represents an infinite series in the multiply periodic atomic system, a schematic representation equivalent to (3) may be given.

From Fig. 1 it is apparent that the variables X and Y are determined by pairs of states, whereas in classical theory variables refer to the same state. Because of this, and in contrast to classical theory, measurements refer not only to an amplitude but also to a temporal ordering of events. Thus an increase in state refers to absorption and a decrease in state refers to emission. As shown in Fig.1 YX corresponds to absorption followed by emission, while XY reverses this order. Because YX and XY do not give the same result we

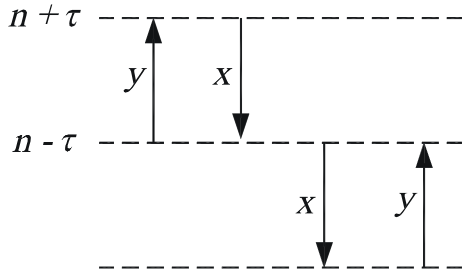

Fig. 1.

are led inevitably to the uncertainty principle and the conclusion that strict causality does not hold [6].

3.2. By recoil momentum

If induced emission is viewed as a direct result of recoil momentum then causality disallows sequences for which emission is followed by absorption. In other words, there is a natural order to radiation processes so that observables *cannot* commute. Non-commutation occurs in quantum theory because Maxwell's equations are reversible in time. As a consequence the formalism of non-relativistic quantum mechanics does not provide a means for describing the natural ordering of events that occurs in radiation processes.

A model of the photon is required that can describe the temporal ordering of radiation processes due to recoil momentum and also exhibits classical wave behavior. Let the photon be assigned the same general characteristics as charged particles: an impenetrable core surrounded by a classically defined field extending to infinity (see also 2, point 2). Elastic collisions by the core involve the particle as a whole. Wave behavior, on the other hand, is due to the local cancellation or reinforcement of field and does not involve the particle as a whole. Photons only exhibit particle behavior when the core is influenced; that is, when momentum is quantized. We may interpret complementarity therefore as the involvement of one or the other of these two aspects of the photon in an interaction.

3.3. Light beam structure

If the photon's electromagnetic field is a single cycle then its net, or time-averaged field intensity is zero and it cannot be detected by a field measurement. Thus *the smallest unit of electromagnetic radiation that can be detected by means of a field measurement is the wave packet.* Wave packets are conceived of as the superposition of many photons and are "assembled" piecemeal in free space. This occurs when spontaneously emitted photons traverse dense populations of excited atomic states, collide elastically with bound photons, and thus cause localized cascades to occur. Photons of a single cycle are thereby correlated into continuous chains of many cycles and into wave packets whose density is related to the density of excited atomic states (the excitation density); and the packets are observed through the local reinforcement of field by linear superposition. Because detection processes are spatially and temporally averaged rather than instantaneous, these correlations appear to an observer to have a well-defined coherence length and width. Therefore light emitted by a thermal source is conceived of as having a highly complex microscopic structure rather than a continuous, uniformly expanding wave front as in classical theory.

4. Energy conservation

4.1. By Fourier analysis

A quantum reformulation of the Fourier series that represent the position coordinates of an electron in a given stationary state contains transition amplitudes, i.e. it involves pairs of states. When variables of this type are used in the equations of motion it is not clear how to express the energy of the system and its time dependence. Heisenberg solved this problem in his introductory paper on quantum mechanics by assuming the time independence of the stationary states and applying energy conservation to the electron as anharmonic oscillator [7]. Thus continuous radiation fields are governed by fictitious harmonic oscillators and an electron's changes of state are described by the anharmonic oscillator. No clear physical connection exists between the anharmonically oscillating electron and the harmonically oscillating radiation it emits.

4.2. By Induced Emission

A physical connection between electron and radiation may be established by means of a precise implementation of the conservation laws. This is accomplished by introducing the concept of "electron oscillator", one cycle of which is defined to be an electron's displacement into a different energy state and its subsequent return to the original state. Thus a different interpretation of the energy matrix $A = a_{ij}$ is required. The off-diagonal elements, $i \neq j$, represent one-half cycle of the electron oscillator and one complete cycle of an electro-magnetic wave. The diagonal elements of the array, $i = j$, represent one complete cycle of the electron; and include both absorption, i.e. photon capture, and emission. Energy conservation is automatically satisfied if photon number is conserved.

One complete cycle of the electron oscillator is equal to two complete cycles of an electromagnetic wave (i.e. two photons) and results in a doubling of the frequency of oscillation. The same thing is observed to occur when the wave function of a half odd integer spin particle is rotated through 4π radians [8]. If we interpret the wave function as a photon-particle pair then a "rotation" of 2π radians corresponds to one cycle of an electromagnetic wave (one photon) and 4π radians equals 2 photons. Thus one rotation of the wave function corresponds to an absorbed photon while two rotations corresponds to absorption and emission, and a return to the ground state.

4.3. By Spontaneous Emission

A satisfactory explanation can now be given for the frequency doubling that occurs in liquid helium due to thermal flow, and is manifested as turbulence [9]. Its similarity to the proposed model of atomic emission suggests that this is the macroscopic form of a quantum transition. Because it is caused by the absorption of heat energy and occurs at random times we may conclude that it is a form of spontaneous emission. Increases in state are performed classically since they are attributed to linear superpositions of field. Therefore the period doubling that occurs at the onset of chaos is interpreted as coherent energy flow that becomes incoherent due to random spontaneous (or chaotic) emissions by molecules.

It may be assumed in general that coherent emissions are a result of recoil momentum, while incoherence is due to spontaneous emissions. In fact experimental evidence from intensity interferometers discussed in 3.3 suggests that thermal sources emit coherent wave packets randomly interspersed with each other. Although wave packets are locally coherent, their phase is shifted with respect to packets that overlap with it. This leads to a net cancellation of field and reduction in observable field intensity such that the total potential energy of the photons in these beams will be greater than the observed field intensity. Because coherent radiation may differ in intensity from incoherent radiation by a factor of 10^{10} vastly higher energy content is predicted for incoherent light than what is actually observed as field intensity[2] [10]. In other words, if the conservation laws are strictly applied to a thermal source we have for the resulting incoherent radiation,

$$p \gg E/c \tag{4}$$

where p and E are the time-averaged momentum and field intensity.

5. Applications

5.1. Interference

It is well known that intense electric and magnetic fields have no influence on the motion of a photon; nevertheless field intensity is thought to be an indication of photon number. But if force cannot be transmitted to the photon via external field, how is it possible for the opposite to occur? In other words, a central force field that behaves symmetrically in one experiment would then have to act asymmetrically in a second. This does not mean that a photon's field cannot transmit force, only that its *integrated* field cannot. Unlike charged particles photons have fields of both polarities. Thus photons have net field strengths of zero and behave as classical field sources unless momentum is exchanged. *It is the exchange of momentum not energy that determines whether photons can be observed.*

The fact that photons have not been observed in interference experiments is easily understood from 2.0, points 4 and 5 if a photon's transverse field is conceived of as falling off slowly. Cancellation and reinforcement may then be described in terms of the local action of superposed fields. Young's double slit interference experiment is interpreted therefore as the involvement of a photon's core and its field in successive interactions. Changes in trajectory at the slits are a result of momentum exchange with the core, while detection at the screen is determined by a superposition of field. In order for momentum to be conserved a uniform distribution is assigned to photons arriving at the screen. Energy, on the other hand, is determined by the superposition of field, rather than the arrival of photons.

Particle behavior in an interference experiment may be verified directly if a way to measure the momentum of photons arriving at the screen can be devised. A second method takes advantage of the distinct properties of a photon's core and its field as described in 2.0, points 4 and 5. If the photons from a dark fringe are reflected and then magnified, they will be displaced laterally by the lens (Fig. 2). The fields will then be separated from each other physically and may be observed as phase shifted components of light [11].

5.2. The significance of light beam structure in astronomical observations

The extremely high excitation densities that exist in stars make differences between starlight and other light forms inevitable. This is because the ratio between induced and spontaneous emission in starlight will be far greater than for any other form of light. As the rays of starlight gradually diverge the transverse fields of overlapping wave packets will be exposed reducing field cancellation and causing an increase in observable light when integrated over the expanding spherical wave front. It means that the structure of starlight changes as it propagates such that its visibility decreases more slowly than other light.

Photometry received from the wide field and planetary camera (WFPC2) of the Hubble telescope seems

[2] Measurements of field intensity indicate that coherent light may contain as many as 10^{16} photons/cm^3 as compared to a maximum of 10^6 photons/cm^3 for incoherent light.

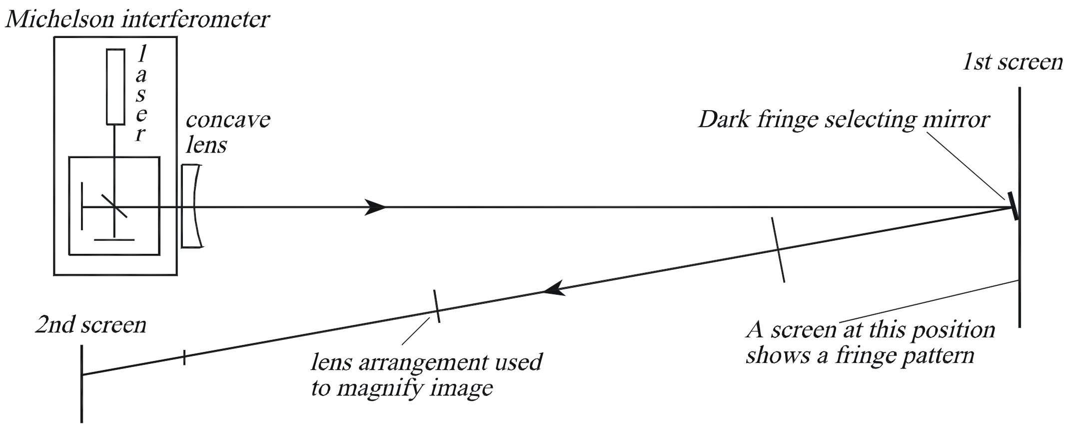

Fig. 2.

to support these ideas since it shows an apparent increase in the visibility of weak starlight (stars so faint they can only be detected by longer exposures). Long exposures collect more light than short exposures and cause star magnitudes to appear greater, leading to the so-called "long vs. short" anomaly [12]. Error analysis has concentrated on techniques that are used for "zero point" calibration and the physical characteristics of CCD's, but attempts to correct data based upon these methods still meet with inconsistent results. Due to the persistence of these and other nonlinearities the effect is judged to be "not fully understood" [13]. However, the possibility that the long vs. short anomaly is due to light beam structure has not been examined.

In order to determine if the nonlinearities in starlight are caused by the properties of light itself it will be necessary to determine whether they are also present in monochromatic thermal sources. This may be accomplished by measuring the total counts for various time periods of very low intensity (i.e. highly diffracted) light.

Systematic changes in the intensity of light could also be caused by spatial coherence as in 5.1. Evidence for its existence in "incoherent" light is sought by comparing the intensity of a highly diffracted beam before and after magnification. If light intensity is proportional to photon number then beam intensity will be unchanged. The validity of the inverse square law for electromagnetic radiation ultimately depends upon the outcome of these studies.

6. Conclusion

The need to take into account the momentum exchange between radiation fields and radiating systems was first pointed out by Einstein when he predicted the existence of "needle rays" [14]. Now there is experimental confirmation of the existence of recoil momentum in radiation processes so that photons may be introduced into non-relativistic quantum mechanics formally. This is possible by using the three body model of the atom to represent the physical content of a system of three continuous field sources. Quantum mechanics may be interpreted therefore as a procedure for solving the equations of motion of an isolated system of three field sources; positive $1/r^2$ dependence, negative $1/r^2$ dependence, and an axially symmetric sinusoidal field with $1/r$ dependence (see appendix).

Finally it should be noted that the three body model may have universal validity since it is the only model of force for which perfect symmetry exists. Thus forces are conceived of as taking on independent existence as embodiments of the intersecting/ overlapping fields of particles, the field sources. In fact independent structure is evident in all the known forces; gravitational, electro-weak, and strong. At one end of the energy spectrum, in general relativity theory, gravitational forces have a well-defined global structure that is independent of the structure of contributing particles. The same is true at the other end in quantum chromodynamics where we see that asymptotic freedom requires strong forces to possess independent structure in the form of a vector boson, or "gluon".

Appendix

The complex formalism of non-relativistic quantum mechanics can be given a relatively simple physical description based on the three body model of atomic states. The Schroedinger picture places time dependence in the state. In the case of the hydrogen atom this consists of a stationary or standing de Broglie matter wave extending around the circumference of the atom with a length that is a whole multiple of the wavelength. If we separate the state, or wave function, into photon and electron it allows us to picture the time dependence of the state in terms of transverse fields oscillating inwards and outwards with respect to the nucleus such that the electron follows in a direction normal to the atom's circumference. This corresponds to the mathematical requirement that energy eigenfunctions be normalized with respect to a box enclosing the nucleus [15]. In other words, the wave function describes an electron, whether in a bound or free state, that is under the influence of a photon's transverse fields.

In the Heisenberg picture the state is independent of time and observables correspond to transitions. Therefore non-commuting observables refer to different states and $\hbar$ is the difference in phase space volume between two stationary states. In the Schroedinger picture because time dependence is in the state, or wave function, $\hbar$ refers directly to the photon's phase space volume. The pictures are mathematically equivalent because they both refer to the same physical space. It is thereby assumed that photons are present in all quantum systems and are the source of all quantum mechanical observables.

An equation of motion for three field sources requires the simultaneous solution of three partial differential equations. Such a solution is not of practical value, however, since there is no test body available to verify its accuracy. A more useful alternative and the one that is actually employed is to determine the dependence of one particle on the combined field of the other two. A solution is obtained therefore by performing two successive mathematical operations. First, a composite of any two vector fields is obtained (the state vector) giving an infinite number of possibilities (the probability amplitudes). The influence of the third vector field (the operator) is then applied giving an infinite number of possible values for the physical variable (the eigenvalues). Each of the eigenvalues represents an exact solution of the equations of motion in terms of a continuous superposition of fields. There are an infinite number of solutions because an infinite number of photons exist that can satisfy the equations.

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References

[1] Oldani R.J. The Fully Quantized Electromagnetic Field // Electromagnetic Phenomena. – 2003. – V 3, N 1(9). – P. 81–86.

[2] Dicke R.H. Coherence in spontaneous radiation processes // Physical Review. – 1954. – V. 93. – P. 99.

[3] Loudon R. The Quantum Theory of Light – London: Oxford. – 2000. – p. 114.

Hanbury Brown R. The Intensity Interferometer – London: Taylor and Francis. – 1970.

[4] Loudon R. The Quantum Theory of Light – London: Oxford. – 2000. – p. 170.

[5] Mehra J., Rechenberg H. The Historical Development of Quantum Theory. V II. – NY: Springer. – 1982–1988. – p. 226.

Jammer M. The Conceptual Development of Quantum Mechanics 2nd ed. – NY: Tomash. – 1989. – p. 213.

[6] Heisenberg W. "Intuitive content of the quantum theoretical kinematics and mechanics" – 1927.

in J.A. Wheeler & W.H. Zurek (eds.), Quantum Theory and Measurement – Princeton: – 1983. – P. 62.

[7] Heisenberg W. "Quantum theoretical reinterpretation of kinematic and mechanical relations" – 1925.

in B.L. van der Waerden (ed.), Sources of Quantum Mechanics – Amsterdam: – 1967. – P. 63;

J. Mehra & H. Rechenberg, op. cit., - P. 253.

[8] L.I. Schiff, Quantum Mechanics – NY: – 1968. – P. 205.

[9] Libchaber A. "Experimental study of hydrodynamic instabilities. Raleigh-Benard experiment: Helium in a small box", in Nonlinear Phenomena at Phase Transitions and Instabilities, ed. T. Riste – NY: Plenum. – 1982. – P. 259.

[10] J.H. Eberly & H.R. Reiss // Phys Rev. – 1966. – V. 176. – P. 1035.

[11] Experiment as performed by D. Chalmers (personal communication)

[12] Casertano, S. & Mutchler. M. "The long vs. short anomaly in WFPC2 images" // Instrument Science Report 98-02. Space Telescope Science Institute. – 1998.

[13] Whitmore B. & Heyer, I. "Charge transfer efficiency for very faint objects and a reexamination of the long vs. short problem for the WFPC2" // Instrument Science Report 2002-03, Space Telescope Science Institute. – 2002. – P. 40.

[14] Einstein A. "On the quantum theory of radiation" (1917), in B.L. van der Waerden (ed.), – P. 63.

[15] L.I. Schiff, op. cit., – P. 47–9.