Quantum Mechanics an Approximation of Classical, Non-Linear Physics?

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Quantum mechanics considers that all particles are well-defined entities. This introduces artifacts which hide very simple explanations, e.g. of the redshift of nebulae. Quantum mechanics appears to be a purely phenomenological theory which hints at the properties of an unknown classical nonlinear system.

Introduction

When the author was asked to teach elementary quantum mechanics, he was eager to do so because he had considerable practice in the field. Generally, year after year, it becomes easier and easier (but not necessarily better and better) to teach the same course. But here, the students were awful, raising so many questions about the foundations of quantum mechanics that an intolerable strife obliged the author to leave this teaching.

Lamb (1995) chose the title “anti-photon” for an exhaustive paper criticizing the quantification of electromagnetic waves. For this paper, I thought first to write an “anti-quantum-mechanics,” but my aim is actually more limited than Lamb’s. I will only criticize specific points, albeit in a broader field. The first part of this paper concerns the pure electromagnetic field, the second concerns the interaction of the field with matter, and the last, matter itself.

A classical equivalent to quantum electrodynamics

Lamb’s arguments may be summarized in one sentence: “Maxwell’s equations are linear.” Quantum electrodynamics bounds photons to modes of electromagnetic waves; but, as complete sets of modes may be defined in an infinity of ways, it is possible to shift from one to the other by a linear transformation, splitting the photons. Quantum mechanics states that the observation defines the set of modes, but, then the EPR paradox appears because the modes can have an infinite extension. Boyer (1975) and Marshall (1989, 1993) showed the equivalence of both electrodynamics, but, some people still maintain that the explanation of certain experiments requires QED, because they are not aware of the correction that Planck (1911) made to his first law on blackbody radiation. This correction, the introduction of a half-quantum of stochastic field in each mode (Nernst 1916), defines stochastic electrodynamics (SED). To avoid an absorption of the whole stochastic field by atoms, Marshall *et al.* (1986) introduce a threshold intensity of the electromagnetic field under which no absorption occurs.

Second order interference

A great many experiments have been done; while they may seem different, their principle is the same (Marshall 1991, Moret-Bailly 1994).

In all experiments two monochromatic incoherent light beams are mixed, and they are incident upon two photoelectric cells. From a conventional interference computation, the first cell receives a field

$$A_1 = A_o \cos(wt + f + k\Delta) + A_o \cos(wt + y - k\Delta) \qquad (1)$$

where f and y are stochastic phases of the light sources and Δ an optical path difference depending, for instance, on the position of the cells. The intensities are:

$$I_1 = I_o \cos^2(d + k\Delta), \quad I_2 = I_o \cos^2(d - k\Delta), \qquad (2)$$

where $\Delta = j - y$. A single cell does not seem to detect any interference. The product $I_1 I_2$ is

$$\frac{I_o^2\left(\cos^2 2d + \cos^2 2k\Delta + \cos d \cos k\Delta\right)}{4}$$

The mean value is

$$\frac{I_o^2\left[(1/2) + \cos^2 2k\Delta\right]}{4} \qquad (3)$$

so that the visibility is $V = 1/2$. The quantum calculation gives $V = 1$, and it appears that experiment leads to the same value.

The criticism of classical theory is weak for two reasons. 1) The experiments are not precise enough to be sure that the experimental visibility is exactly one; it is experimentally difficult and theoretically impossible to set apart the intensities of signal and noise: the signal comes from an amplification of the zero-point field so that both fields are not incoherent. 2) Equation 1 gives the light intensities without the stochastic field, rather than the response of the cells; Equation 2 does not give the count. The non-linearity of the photoelectric cells in the noise accentuates the high level signals and, thus the visibility.

Squeezing of light

Books on electrical technology describe saturated iron transformers which are used to stabilize AC voltages: Consider a transformer with an open secondary, and a primary fed by a sinusoidal current i. If the inductance L is a constant, neglecting the resistances, the voltage at the primary is:

$$v = -L\frac{di}{dt} = -LI\frac{d(\cos wt)}{dt} = Lw\,\sin wt \qquad (3)$$

If the current is large enough to saturate an iron core, between time $t = 0$ and a time small compared to a half-period, the core is quickly desaturated and is in nearly linear conditions; thus Equation (3) is valid. Later, in the same half-period, the core saturates and the voltage is lower than in the equation. The two consequences if I is changed are: i) the active AC voltage is partly stabilized; ii) as the maximal value of v is displaced, the phase of the Fourier component at pulsation w is changed. (In actual systems, a linear inductance is in series with the primary and the mains, and the cores are partly common).

The above theory is easily transposed to explain a type of squeezing of light: The intensity fluctuations of a light beam are reduced as the beam goes through a convenient non-linear medium, and the phase fluctuations are increased. Is Heisenberg's uncertainty principle really the best way to explain how AC saturated iron transformers work?

Interaction of electromagnetic field with matter

Mandel *et al.* (1964), Lamb *et al* (1969) have shown that the photoelectric detection of light may be computed with a semi-classical theory as well as with QED.

A completely classical computation is obtained by a convenient modeling of molecules able to introduce attractors. In classical non-linear mechanics, attractors are equivalent to the stationary states of quantum mechanics. A molecule in a stationary state does not exchange energy with the field so that one can say the molecule has no dipole moment. Thus, for a realistic representation of molecules, the usual correlation between energy and dipole moment must be broken. The dipole moment becomes a function of the molecular parameters which goes to zero in a stationary state.

In the field of thermodynamics, interactions between molecules are typically assumed to be linear, and we get an equipartition of energy. With a strong non-linearity, on the contrary, instabilities appear, and the energy is concentrated in a few particles. This latter behavior is observed for molecules that have non-linear dipole moments connected by the electromagnetic field (Monnot 1994). The configurations of almost all molecules are close to the stationary states; the addition of energy allows some molecules to jump from a lower to a higher state. The threshold intensity of the electromagnetic field postulated by Marshall *et al*. (1986) appears as a property of this model.

This simple model showed the way to an alternative to the Doppler effect, for explaining the redshift of distant nebulae. De Broglie first thought that the light could be "tired." Pecker *et al*. (1988) later proposed the tiring to be the Raman effect. However their proof was insufficient because the spontaneous Raman effect is incoherent. It would destroy the wave fronts and therefore the images, which is contrary to experience. A classical system in which two dipoles are connected can radiate at the frequency of one of the dipoles when the other is excited. This Raman effect is deterministic so that a population of these systems radiates in synchronism, the scattered field is coherent, and the imaging remains. Thermodynamics teaches that in complicated systems, there are losses of energy, leading to the redshift.

The key point is that, as the frequencies are different, the phase of the scattered light depends on the time at which the process started. In usual Raman experiments with monochromatic light, this start is some collision in the gas, so that the coherence is generally lost. With pulsed light (picosecond lasers) however, the coherence is recovered (Lamb 1971). The same occurs with wide bandwidth light (white light) which may be considered as a succession of low energy short incoherent pulses. To get the spatial coherence, it is sufficient that the duration of the coherence in the time be lower than either:

i) the period the beat of frequencies between incident and scattered light
ii) the relaxation time of the refracting medium (see Lamb's paper); in intergalactic space, the pressure is very low, so that this relaxation time is long. Thus, light containing an easily resolvable spectrum is not too coherent in time to be redshifted.

Another equivalent explanation for condition i) is refraction produced by transitions between a (ground state) level and itself, through virtual levels. If the ground state is degenerate, a perturbation which splits the ground state will produce a frequency shift in part of the transitions formerly responsible for refraction. As the perturbation may have continuously any intensity, coherence remains if the frequency shift is small.

The ground state of most atoms is always split by the dynamic Stark effect of the stochastic field (Bethe 1947, Welton 1948). The Zeeman effect can induce a much larger shift near quasars.

The de-excitation of molecules can be partly spontaneous, and a thermal equilibrium between molecules and radiation reached at 2.7 K by the Raman scattering which is much more important for microwaves than for higher frequencies because the density of energy is larger in this region.

A classical theory to which quantum theory is an approximation

A classical image of a stationary state is an attractor of a nonlinear problem. Molecules remain near their attractors, except during the short interval during a transition.

From quantum mechanics we can obtain probabilities, for instance through the Heisenberg uncertainty principle. This principle comes from the study of waves and is a direct application of a property of the Fourier transform. We can obtain very precise spectroscopic data using any one of several closely connected theories involving either the Schrödinger equation, or raising and lowering operators, or Lie algebra. Most of the properties of the convenient Lie algebra comes from the symmetries, while the adjustments of the parameters comes from experimental data.

Thus, quantum mechanics appears to be phenomenological, using the simplest mathematical way to find, with discrete values, the equivalent of interpolations between continuous values. Abandoning the foundations of quantum mechanics established by the Copenhagen school has the big advantage of making the paradoxes (EPR, Schrödinger's cat...) disappear.

It is generally assumed that classical mechanics is an approximation of quantum mechanics. The contrary seems better, but how to find the required classical, non-linear, unknown mechanics? It appears to be difficult because we have almost no mathematics to study non-linear systems.

The linearity of Maxwell equations allows one to easily find a perfect classical theory for radiation. For matter, it seems that it is necessary to start with a simple particle, and the electron seems simple enough. However, all attempts to find internal properties of an electron consistent with the properties of Dirac's electron have failed. A recent attempt to find a classical model is probably not better than Dirac's one (1962) and requires heavy numerical computations (Moret-Bailly, submitted paper); the guiding idea is:

> *Each mode has its half quantum of energy. Because the number of modes is infinite, there is a paradox in the previous sentence if the energy density is assumed to be finite. In QED, a postulate of renormalization deletes the infinite energy; Plank's introduction of the half quantum supposes an equilibrium between matter and radiation so that the half quantum can disappear at high frequency.*

Maxwell equations are linear in vacuum. But, if the frequency multiplied by h is more than a MeV, an electron-positron pair can be created. If matter is not needed as a catalyst for this creation, nonlinear terms must be introduced in Maxwell's equations.

In a nonlinear refractive medium, a powerful laser beam splits into filaments; each of them conducts almost the same amount of energy; their stable shape is a straight line. Imagine that, for the vacuum, one puts into Maxwell's equations nonlinear terms depending on the electric field and on rotational terms; the straight line shape is unstable, and the filaments bend into a torus. The 3-D solitons obtained are not invariant in the conformal group, and have an electric charge because non-linear terms destroy the $\nabla E = 0$ equation. Can more complicated topologies be obtained? May such solitons represent electrons or other particles?

Conclusion

For describing light, classical, stochastic electrodynamics is the best theory thanks to the availability of the necessary mathematics. Quantum mechanics (in this case quantum electrodynamics) is nothing more than a tool to recover some of the results of classical electrodynamics. Expanding this point of view to the physics of particles has the advantage of discarding the scholastic interpretations of quantum mechanics and opening up a new field of research.

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