Electronic version of an article published as
International Journal of Quantum Information,Vol. 9, Suppl. (2011) 17–26
DOI: 10.1142/S0219749911006909 © World Scientific Publishing Company
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International Journal of Quantum Information
Vol. 9, Suppl. (2011) 17–26
© World Scientific Publishing Company
DOI: 10.1142/S0219749911006909

IS NO DRAMA QUANTUM THEORY POSSIBLE?

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Received 24 August 2010

The matter field can be naturally eliminated from the equations of the Klein-Gordon-Maxwell electrodynamics in the unitary gauge. The resulting equations describe independent dynamics of the electromagnetic field: if components of the 4-potential of the electromagnetic field and their first derivatives with respect to time are known in the entire space at some time point, the values of their second derivatives with respect to time can be calculated for the same time point, so the Cauchy problem can be posed, and integration yields the 4-potential in the entire space-time. This surprising result both permits mathematical simplification and can be useful for interpretation of quantum theory. For example, in the Bohm interpretation, the electromagnetic field can replace the wave function as the guiding field. Independent of the interpretation, quantum phenomena can be described in terms of electromagnetic field only. For the system of nonlinear partial differential equations of the Klein-Gordon Maxwell electrodynamics, a generalized Carleman linearization procedure generates a system of linear equations in the Hilbert space, which looks like a second-quantized theory and is equivalent to the original nonlinear system on the set of solutions of the latter. Similar, but less general results are obtained for the Dirac-Maxwell electrodynamics.

Keywords: Dirac's "new electrodynamics"; Bohm interpretation; locality.

1. Introduction

Is it possible to offer a "no drama" quantum theory? Something as simple (in principle) as classical electrodynamics — a local realistic theory described by a system of partial differential equations in 3+1 dimensions, but reproducing unitary evolution of quantum theory in the configuration space?

Of course, the Bell inequalities cannot be violated in such a theory. This author has little, if anything, new to say about the Bell theorem, and this article is not about the Bell theorem. However, this issue cannot be "swept under the carpet" and will be discussed in Section 5 using other people's arguments.

In Dirac's "new electrodynamics" (Ref. [1]), the gauge condition of classical electrodynamics is chosen in such a way that the resulting equations of motion for the potentials of the electromagnetic field (the Maxwell equations) also describe motion of electrons in accordance with the Lorentz equations. Schrödinger (Ref. [2])

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applied Dirac's approach to a quantum theory – (non-second-quantized) scalar electrodynamics (Klein-Gordon-Maxwell electrodynamics). He demonstrated that the equations obtained in the unitary gauge (Ref. [3],[4]), where the charged matter field is real, closely resemble those of "new electrodynamics". However, to the best of this author's knowledge, it was not noticed then or later that the equations of Schrödinger's work share another unique and important feature of "new electrodynamics": after natural and possibly obvious elimination of the matter field wave function, they also describe independent dynamics of electromagnetic field in the following sense: if components of the 4-potential of the electromagnetic field and their first derivatives with respect to time are known in the entire space at some time point, the values of their second derivatives with respect to time can be calculated for the same time point, so the Cauchy problem can be posed, and integration yields the 4-potential in the entire space-time. Thus, the broad range of quantum phenomena described by Klein-Gordon-Maxwell electrodynamics can be described in terms of electromagnetic field only. This unexpected result not only permits mathematical simplification, as the number of fields is reduced, but can also be useful for interpretation of quantum theory. For example, in the Bohm (de Broglie-Bohm) interpretation (Refs. [5,6,7]), the electromagnetic field can replace the wave function as the guiding field. This may make the interpretation more attractive, removing, for example, the reason for the following criticism of the Bohm interpretation: "If one believes that the particles are real one must also believe the wavefunction is real because it determines the actual trajectories of the particles. This allows us to have a realist interpretation which solves the measurement problem, but the cost is to believe in a double ontology. [8]" Independent of the interpretation, quantum phenomena can be described in terms of electromagnetic field only.

Similar, but less general results are derived for the Dirac-Maxwell electrodynamics.

It is also shown (using other people's results) how the "one-particle" theories can be turned into "many-particle" theories, which look very much like quantum field theory, with little or no extra complications.

2. Dirac's "New Electrodynamics"

This work heavily uses the results of Refs. [1,2], so let us summarize and reformulate some of them here (a system of units where $c = \hbar = 1$ is used). In Ref. [1], Dirac considers the following conditions of stationary action for the free electromagnetic field Lagrangian subject to the constraint $A_\mu A^\mu = k^2$ (k is a constant):

$$\Box A_\mu - A^\nu_{,\nu\mu} = \lambda A_\mu, \tag{1}$$

where A^μ is the potential of the electromagnetic field, and $\lambda = \lambda(x)$ is a Lagrange multiplier. The constraint represents a nonlinear gauge condition. One can assume that the conserved current in the right-hand side of Eq. (1) is created by a distri-

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bution of particles of mass m, charge e, and 4-velocity

$$u^\mu = \frac{dx^\mu}{d\tau} = \frac{1}{\sqrt{1-\mathbf{v}^2}}(1, \mathbf{v}) = \zeta A^\mu, \tag{2}$$

where τ is the proper time of the particle ($(d\tau)^2 = dx^\mu dx_\mu$), $\mathbf{v} = (v^1, v^2, v^3)$ is 3-velocity, and ζ is a constant. If these particles move in accordance with the Lorentz equations (Ref. [9], §23)

$$\frac{du^\mu}{d\tau} = \frac{e}{m} F^{\mu\nu} u_\nu, \tag{3}$$

where $F^{\mu\nu} = A^{\nu,\mu} - A^{\mu,\nu}$ is the electromagnetic field, then

$$\frac{du^\mu}{d\tau} = u^{\mu,\nu}\frac{dx_\nu}{d\tau} = u_\nu u^{\mu,\nu} = \zeta^2 A_\nu A^{\mu,\nu}. \tag{4}$$

Due to the constraint, $A_\nu A^{\nu,\mu} = 0$, so

$$A_\nu A^{\mu,\nu} = -A_\nu F^{\mu\nu} = -\frac{1}{\zeta} F^{\mu\nu} u_\nu. \tag{5}$$

Therefore, Eqs. (3,4,5) are consistent if $\zeta = -\frac{e}{m}$, and then $u_\mu u^\mu = 1$ implies $k^2 = \frac{m^2}{e^2}$ (so far the discussion is limited to the case $-\frac{e}{m}A^0 = u^0 > 0$).

Thus, Eq. (1) with the gauge condition

$$A_\mu A^\mu = \frac{m^2}{e^2} \tag{6}$$

describes both independent dynamics of electromagnetic field and consistent motion of charged particles in accordance with the Lorentz equations. The words "independent dynamics" mean that the Cauchy problem can be posed: if values of the spatial components A^i of the potential ($i = 1, 2, 3$) and their first derivatives with respect to x^0 ($\dot{A}^i$) are known in the entire space at some time point ($x^0 = \text{const}$), then A^0, $\dot{A}^0$ can be eliminated using Eq. (6), λ can be eliminated using Eq. (1) for $\mu = 0$ (the equation does not contain second derivatives with respect to x^0 for $\mu = 0$), and the second derivatives with respect to x^0 ($\ddot{A}^i$), can be determined from Eq. (1) for $\mu = 1, 2, 3$.

3. Elimination of Matter Field from Scalar Electrodynamics

In his comment on the Dirac's work, Schrödinger (Ref. [2]) considered interacting scalar charged field ψ and electromagnetic field $F^{\mu\nu}$ with the Lagrangian

$$-\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}(\psi^*_{,\mu} - ieA_\mu\psi^*)(\psi^{,\mu} + ieA^\mu\psi) - \\ -\frac{1}{2}m^2\psi^*\psi \tag{7}$$

and the Klein-Gordon-Maxwell equations of motion

$$(\partial^\mu + ieA^\mu)(\partial_\mu + ieA_\mu)\psi + m^2\psi = 0, \tag{8}$$

$$\Box A_\mu - A^\nu_{,\nu\mu} = j_\mu, \tag{9}$$

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$$j_\mu = ie(\psi^*\psi_{,\mu} - \psi^*_{,\mu}\psi) - 2e^2 A_\mu \psi^*\psi. \tag{10}$$

For each solution A^μ, ψ of these equations there is a physically equivalent (i.e. coinciding with it up to a gauge transform) solution B^μ, φ, where φ is real. For real scalar field, the equations of motions can be written in the following form (see also Ref. [3]):

$$\Box\varphi - (e^2 B^\mu B_\mu - m^2)\varphi = 0, \tag{11}$$

$$\Box B_\mu - B^\nu_{,\nu\mu} = j_\mu, \tag{12}$$

$$j_\mu = -2e^2 B_\mu \varphi^2. \tag{13}$$

Schrödinger emphasized two circumstances. Firstly, except for the missing constraint, the equations for the electromagnetic potentials coincide with Eq. (1) (if we replace B_μ with A_μ and $-2e^2\varphi^2$ with λ). Secondly, the fact that the scalar field can be made real by a change of gauge, although easy to understand, contradicts the widespread belief about charged fields requiring complex representation.

Obviously, the equations for B_μ and φ are not gauge invariant, as the gauge has already been fixed by the condition that φ is real – unitary gauge (Refs. [3],[4]). It should be noted that these equations can be obtained from the following Lagrangian (Ref. [10]):

$$-\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}e^2 B_\mu B^\mu \phi^2 + \frac{1}{2}(\varphi_{,\mu}\varphi^{,\mu} - m^2\varphi^2). \tag{14}$$

Actually, it coincides with the Lagrangian of Eq. (7) up to the replacement of the complex scalar field by a real one.

Rather surprisingly, Eqs. (11,12,13) also describe independent dynamics of electromagnetic field in the following sense (assuming φ and B^0 do not vanish identically): if components B^μ of the potential and their first derivatives with respect to x^0 ($\dot{B}^\mu$) are known in the entire space at some time point ($x^0 = \text{const}$), Eqs. (11,12,13) yield the values of their second derivatives, $\ddot{B}^\mu$, for the same value of x^0, so integration yields B^μ for any value of x^0. Indeed, φ can be eliminated using Eq. (12) for $\mu = 0$, as this equation does not contain $\ddot{B}^\mu$ for this value of μ:

$$\varphi = \sqrt{(-2e^2 B_0)^{-1}(\Box B_0 - B^\nu_{,\nu 0})}. \tag{15}$$

Then $\ddot{B}^i$ ($i = 1, 2, 3$) can be determined by substitution of Eqs. (13,15) into Eq. (12) for $\mu = 1, 2, 3$. Conservation of current implies

$$0 = \partial_\mu(B^\mu\varphi^2) = (\partial_\mu B^\mu)\varphi^2 + 2B^\mu\varphi\partial_\mu\varphi, \tag{16}$$

or

$$0 = (\partial_\mu B^\mu)\varphi + 2B^\mu\partial_\mu\varphi = (\dot{B}^0 + B^i_{,i})\varphi + 2B^0\dot{\varphi} + 2B^i\varphi_{,i} \tag{17}$$

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(Greek indices in the Einstein sum convention run from 0 to 3, and Latin indices run from 1 to 3). This equation determines $\dot{\varphi}$, as spatial derivatives of φ can be found from Eq. (15). Differentiation of this equation yields

$$0 = (\ddot{B}^0 + \dot{B}^i_{,i})\varphi + (\dot{B}^0 + B^i_{,i})\dot{\varphi} + \\ +2(\dot{B}^0\dot{\varphi} + B^0\ddot{\varphi} + \dot{B}^i\varphi_{,i} + B^i\dot{\varphi}_{,i}). \tag{18}$$

After substitution of φ from Eq. (15), $\dot{\varphi}$ from the previous equation, and $\ddot{\varphi}$ from Eq. (11) into Eq. (18), the latter equation determines $\ddot{B}^0$ as a function of B^μ, $\dot{B}^\mu$ and their spatial derivatives (again, spatial derivatives of φ and $\dot{\varphi}$ can be found from the expressions for φ and $\dot{\varphi}$ as functions of B^μ and $\dot{B}^\mu$). Thus, if B^μ and $\dot{B}^\mu$ are known in the entire space at a certain value of x^0, then $\ddot{B}^\mu$ can be calculated for the same x^0, so integration yields B^μ in the entire space-time. Therefore, we do have independent dynamics of electromagnetic field, although one cannot choose arbitrary values of B^μ and $\dot{B}^\mu$ at a certain time point as, for example, the argument of the square root in Eq. (15) must not be negative. However, there is no need to prove that the set of solutions of the relevant equations is broad enough, as it includes all solutions of the Klein-Gordon-Maxwell equations Eqs. (8,9,10) (up to a gauge transform). If φ or B^0 vanish identically, the dynamics of electromagnetic field is also independent but different. This indicates that the dynamics can be sensitive to arbitrarily small fields.

Apparently, it is possible to introduce a Lorentz-invariant Lagrangian with higher derivatives that does not include the matter field, but is largely equivalent to the Lagrangian of Eq. (14) (the significance of some special cases, e.g., $\varphi = 0$ and $B^\mu B_\mu = 0$ (see below) is unclear (different particles?)). To this end, the latter Lagrangian can be expressed in terms of φ^2, rather than φ, using, e.g., the following:

$$\varphi_{,\mu}\varphi^{,\mu} = \frac{1}{4}\frac{(\varphi^2)_{,\mu}(\varphi^2)^{,\mu}}{\varphi^2}, \tag{19}$$

and then φ^2 can be replaced by the following expression obtained from the equations of motion Eqs. (12,13):

$$\varphi^2 = -\frac{1}{2e^2}\frac{B^\mu(\Box B_\mu - B^\nu_{,\nu\mu})}{B^\mu B_\mu}. \tag{20}$$

It should be noted that this article only deals with local, rather than global properties of the relevant equations, although global properties can also be physically important.

The result on the independent dynamics of electromagnetic field remains valid if conserved external currents are added to the right-hand side of the Maxwell equations (Eqs. (9)). This is important for description of the hydrogen atom, the Aharonov-Bohm effect, and other quantum phenomena in terms of electromagnetic field only.

This result can also be relevant to interpretation of quantum theory. For example, it allows an interesting modification of the Bohm interpretation (Refs. [5,6,7]).

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Loosely speaking, in the Bohm interpretation (for one particle) the charged field represents an ensemble of point-like particles guided by the field and moving along the lines of current. For example, for the Klein-Gordon field, the current is defined by Eq. (10) or Eq. (13). The results of this work suggest that electromagnetic field, rather than the matter field wave function, can be regarded as the guiding field, and in each point the particles move along the potential B^μ.

It should be mentioned that there is some controversy about the Bohm interpretation of the Klein-Gordon field, in particular, because current may be spacelike for this field. For example, in Refs. [11,12] it is contended that these difficulties do not lead to inconsistencies; a different definition of particle trajectories is given in Refs. [13,14] (see, however, Ref. [15]); there is also an opinion that bosons are fields, and they have no particle trajectories (Ref. [6]). This author focuses, however, on electrodynamics and does not consider any massive bosons, so the Klein-Gordon equation is regarded just as a reasonably decent approximation for electrons. Therefore, the inevitable next step would be to replace the Klein-Gordon field by the Dirac field. However, the latter has more components than the former, so the approach of this article yields less general results for Dirac-Maxwell electrodynamics (Ref. [16], pp. 4-5, Ref. [17]). The results for the Dirac field are presented in the next section. Other gauge theories (such as the Standard Model) have not been considered yet. As for second-quantized theories, nightlight (Ref. [18]) indicated that such theories can be obtained from nonlinear partial differential equations by a generalization of the Carleman linearization procedure (Ref. [19]). This procedure generates for a system of nonlinear partial differential equations a system of linear equations in the Hilbert space, which looks like a second-quantized theory and is equivalent to the original nonlinear system on the set of solutions of the latter.

Let us consider a nonlinear differential equation in an (s+1)-dimensional space-time (the equations describing independent dynamics of electromagnetic field for scalar electrodynamics are a special case of this equation) $\partial_t \boldsymbol{\xi}(x,t) = \boldsymbol{F}(\boldsymbol{\xi}, D^\alpha \boldsymbol{\xi}; x, t)$, $\boldsymbol{\xi}(x,0) = \boldsymbol{\xi}_0(x)$, where $\boldsymbol{\xi} : \mathbf{R}^s \times \mathbf{R} \to \mathbf{C}^k$, $D^\alpha \boldsymbol{\xi} = (D^{\alpha_1}\xi_1, \ldots, D^{\alpha_k}\xi_k)$, α_i are multiindices, $D^\beta = \partial^{|\beta|}/\partial x_1^{\beta_1} \ldots \partial x_s^{\beta_s}$, with $|\beta| = \sum_{i=1}^{s} \beta_i$, is a generalized derivative, $\boldsymbol{F}$ is analytic in $\boldsymbol{\xi}$, $D^\alpha \boldsymbol{\xi}$. It is also assumed that $\boldsymbol{\xi_0}$ and $\boldsymbol{\xi}$ are square integrable. Then Bose operators $\boldsymbol{a^\dagger(x)} = \left(a_1^\dagger(x), \ldots, a_k^\dagger(x)\right)$ and $\boldsymbol{a(x)} = (a_1(x), \ldots, a_k(x))$ are introduced with the canonical commutation relations:

$$\left[a_i(x), a_j^\dagger(x')\right] = \delta_{ij}\delta(x - x')I,$$
$$[a_i(x), a_j(x')] = \left[a_i^\dagger(x), a_j^\dagger(x')\right] = 0, \tag{21}$$

where $x, x' \in \mathbf{R}^s$, $i, j = 1, \ldots, k$. Normalized functional coherent states in the Fock space are defined as $|\boldsymbol{\xi}\rangle = \exp\left(-\frac{1}{2}\int d^s x |\boldsymbol{\xi}|^2\right) \exp\left(\int d^s x \boldsymbol{\xi}(x) \cdot \boldsymbol{a}^\dagger(x)\right)|\mathbf{0}\rangle$. They have the following property:

$$\boldsymbol{a}(x)|\boldsymbol{\xi}\rangle = \boldsymbol{\xi}(x)|\boldsymbol{\xi}\rangle, \tag{22}$$

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Then the following vectors in the Fock space can be introduced:

$$|\xi, t\rangle = \exp\left[\frac{1}{2}\left(\int d^s x|\boldsymbol{\xi}|^2 - \int d^s x|\boldsymbol{\xi}_0|^2\right)\right]|\boldsymbol{\xi}\rangle$$
$$= \exp\left(-\frac{1}{2}\int d^s x|\boldsymbol{\xi}_0|^2\right)\exp\left(\int d^s x\boldsymbol{\xi}(x)\cdot\boldsymbol{a}^\dagger(x)\right)|\mathbf{0}\rangle. \tag{23}$$

Differentiation of Eq. (23) with respect to time t yields, together with Eq. (22), a linear Schrödinger-like evolution equation in the Fock space:

$$\frac{d}{dt}|\xi, t\rangle = M(t)|\xi, t\rangle,$$
$$|\xi, 0\rangle = |\boldsymbol{\xi}_0\rangle, \tag{24}$$

where the boson "Hamiltonian" $M(t) = \int d^s x\boldsymbol{a}^\dagger(x)\cdot F(\boldsymbol{a}(x), D^\alpha\boldsymbol{a}(x))$.

4. Application to Dirac-Maxwell Electrodynamics

The Schrödinger's remark on the possibility of description of charged particles with real fields suggests that charged particles of spin 1/2 may be described by Majorana spinors (actually, Majorana developed his theory (Ref. [20]) for electrons), as the Majorana condition is an analog of the reality condition and coincides with the latter in the Majorana representation of γ-matrices (Ref. [4]). However, in a general case, a complex 4-spinor cannot be turned into a Majorana spinor by a gauge transform, so we shall start with a less general theory. So far we have only considered solutions of a well-established theory – the Klein-Gordon-Maxwell electrodynamics, so in this respect we have been on firm ground, no matter how controversial its interpretation may be. Now let us consider the standard Lagrangian of the Dirac-Maxwell electrodynamics and impose the constraint $\bar{\Psi}\gamma^\mu\gamma^5\Psi = 0$ (the axial current vanishes). A similar approach to imposition of the Majorana condition was used in Ref. [21], but the specific procedure there raises some doubts as the constraints of that work make no contribution to the equations of motion. In our case the equations of motion are as follows:

$$(i\partial\!\!\!/ - eA\!\!\!/ + D\!\!\!\!/\gamma^5 - m)\Psi = 0, \tag{25}$$

$$\Box A_\mu - A^\nu_{,\nu\mu} = j_\mu, \tag{26}$$

$$j_\mu = e\bar{\Psi}\gamma_\mu\Psi, \tag{27}$$

$$\bar{\Psi}\gamma^\mu\gamma^5\Psi = 0, \tag{28}$$

where, e.g., $D\!\!\!\!/ = D_\mu\gamma^\mu$ (the Feynman slash notation), and D_μ are the Lagrangian multipliers. Every solution of this system is physically equivalent to a Majorana solution related to it via a gauge transform: Eq. (28) implies that the spinor Ψ may be represented in the form $\Psi = \exp(i\theta)\Phi$, where $\theta = \theta(x)$ is real, and Φ is a spinor

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satisfying the Majorana condition. Substituting this in Eqs. (25,26,27), we obtain equations for Majorana spinors:

$$(i\partial\!\!\!/ - eB\!\!\!/ + D\!\!\!\!/\gamma^5 - m)\Phi = 0, \tag{29}$$

$$\Box B_\mu - B^\nu_{,\nu\mu} = j_\mu, \tag{30}$$

$$j_\mu = e\bar{\Phi}\gamma_\mu\Phi, \tag{31}$$

where $eB_\mu = eA_\mu + \theta_{,\mu}$. Applying charge conjugation to Eq. (29) and using the Majorana condition, we obtain:

$$(i\partial\!\!\!/ + D\!\!\!\!/\gamma^5 - m)\Phi = 0, \tag{32}$$

$$B\!\!\!/\Phi = 0. \tag{33}$$

Eq. (33) implies $B_\mu B^\mu = 0$, if $\Phi \neq 0$; if the vector B^μ is not zero, the equation also implies that there exists such λ that $j^\mu = \lambda B^\mu$. Therefore, we obtain the following system of equations with Majorana spinors:

$$(i\partial\!\!\!/ + D\!\!\!\!/\gamma^5 - m)\Phi = 0, \tag{34}$$

$$B_\mu B^\mu = 0, \tag{35}$$

$$\lambda B^\mu = j^\mu = e\bar{\Phi}\gamma^\mu\Phi, \tag{36}$$

$$\Box B_\mu - B^\nu_{,\nu\mu} = \lambda B_\mu. \tag{37}$$

Eq. (34) is linear in D_μ, so it is easy to eliminate D_μ from it. Again, Eqs. (35,37) describe independent evolution of the electromagnetic field, and Eq. (36) allows one to determine the trajectories in the Bohm interpretation from the potential of the electromagnetic field. It remains to be seen whether Eqs. (34,35,36,37) are compatible with experimental data or they may only be used as an interesting toy model for interpretation of quantum mechanics.

5. Bell Theorem

In Section 3, it was shown that a theory similar to quantum field theory (QFT) can be built that is basically equivalent to non-second-quantized scalar electrodynamics on the set of solutions of the latter. However, the local realistic theory does not violate the Bell inequalities, so this issue is discussed below using other people's arguments. Most of them were outlined by nightlight in various forums (see, e.g., Ref. [22]) and by Santos (e.g.Ref. [23]), and can be summarized as follows.

While the Bell inequalities cannot be violated in local realistic theories, there are some reasons to believe these inequalities cannot be violated either in experiments or in quantum theory. Indeed, there seems to be a consensus among experts that "a

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conclusive experiment falsifying in an absolutely uncontroversial way local realism is still missing" [24]. For example, Shimony offers the following opinion:

"The incompatibility of Local Realistic Theories with Quantum Mechanics permits adjudication by experiments, some of which are described here. Most of the dozens of experiments performed so far have favored Quantum Mechanics, but not decisively because of the "detection loophole" or the "communication loophole." The latter has been nearly decisively blocked by a recent experiment and there is a good prospect for blocking the former. [25]"

Aspelmeyer and Zeilinger agree:

"But the ultimate test of Bells theorem is still missing: a single experiment that closes all the loopholes at once. It is very unlikely that such an experiment will disagree with the prediction of quantum mechanics, since this would imply that nature makes use of both the detection loophole in the Innsbruck experiment and of the locality loophole in the NIST experiment. Nevertheless, nature could be vicious, and such an experiment is desirable if we are to finally close the book on local realism." [26]

The popular argument of the latter quote that the loopholes were closed in separate experiments does not look conclusive either. Otherwise one could argue, for example, that the sum of the angles of a triangle in planar Euclidian geometry can differ from 180 degrees because experiments demonstrate that the sum of angles can differ from 180 degrees for planar quadrangles and for triangles on a sphere. The Bell inequalities for local realistic theories can only be guaranteed if all conditions of the Bell theorem are fulfilled simultaneously.

Second, to prove theoretically that the inequalities can be violated in quantum theory, one needs to use the projection postulate (loosely speaking, the postulate states that if some value of an observable is measured, the resulting state is an eigenstate of the relevant operator with the relevant eigenvalue). However, such postulate, strictly speaking, is in contradiction with the standard unitary evolution of the larger quantum system that includes the measured system and the measurement device (and the observer, if you wish), as such postulate introduces irreversibility, whereas there is no irreversibility for the larger system (see, e.g. Ref. [27] or the references to journal articles there), and, according to the quantum recurrence theorem, the larger system will return to a state that can be arbitrarily close to its initial, pre-measurement state. Furthermore, unitary evolution cannot generate a mixture of states (the well-known measurement problem in quantum theory). Therefore, mutually contradictory assumptions are required to prove the Bell theorem, so it is on shaky grounds both theoretically and experimentally.

6. Conclusion

It is shown that scalar electrodynamics (Klein-Gordon-Maxwell electrodynamics) in the unitary gauge provides a closed system of partial differential equations for electromagnetic field and thus describes independent dynamics of electromagnetic field.

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Similar, but less general results are obtained for the Dirac-Maxwell electrodynamics. For scalar electrodynamics, the Carleman linearization procedure can provide a theory that is very similar to quantum field theory and basically equivalent to scalar electrodynamics on the set of solutions of the latter.

So is a no drama quantum theory possible? Using a popular phrase, "I'll give you a definite maybe".

Acknowledgments

The author is grateful to A.E. Allahverdyan, A.V. Gavrilin, A.Yu. Kamenshchik, A.Yu. Khrennikov, nightlight, H. Nikolić, W. Struyve, and H. Westman for their interest in this work and valuable remarks.

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