A particle-free model of matter based on electromagnetic self-confinement (I)

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ABSTRACT. This article sets out to demonstrate that electromagnetic radiation with an energy density in the order of magnitude of $10^{73}(J/m^3)$ satisfies the condition of stability for gravitational self-confinement, while its corresponding electromagnetic vector wave function satisfies the classic Schrödinger wave equation. The complex electromagnetic vector wave function is denoted in this article by $\overrightarrow{\Phi}(\overrightarrow{x},t)$ and exhibits a correspondence with the scalar quantum-mechanical complex probability function $\Psi(\overrightarrow{x},t)$, that cannot be explained by chance. The electromagnetic model also admits other forms of self-confinement of electromagnetic radiation, including electro-magneto-static self- confinement at considerably lower energy densities, in which circumstances the descriptive complex electromagnetic wave function also satisfies the Schrödinger wave equation.

RÉSUMÉ.
Il est montré dans cet article qu'un rayonnement électromagnétique à densité énergétique d'un ordre de grandeur de $10^{73}(J/m^3)$ *satisfait la condition de stabilité pour l'autoconfinement gravitationnel et que, par conséquent, la fonction d'onde vectorielle électromagnétique correspondante satisfait la classique équation d'onde de Schrödinger. Désignée* $\overrightarrow{\Phi}(\overrightarrow{x},t)$ *dans cet article, la fonction vectorielle d'onde électromagnétique complexe présente une concordance qui ne peut être considérée comme fortuite avec la fonction de probabilité complexe de la mécanique quantique scalaire,* $\Psi(\overrightarrow{x},t)$. *Le modèle électromagnétique autorise également d'autres formes d'autoconfinement du rayonnement électromagnétique, notamment l'autoconfinement électro-magnétostatique avec des densités énergétiques beaucoup plus faibles, en quel cas la fonction d'onde électromagnétique complexe descriptive satisfait également la fonction d'onde de Schrödinger.*

1. Introduction.

The most important developments in particle physics are based on a fundamental discontinuity in the composition of matter, that is implied by each underlying particle model. This article describes an electromagnetically continuous model of matter that does not use the concept of elementary particles, but only of gravitationally or electro- magnetostatically self-confined electromagnetic radiation in a perfect vacuum. The model should be regarded as a component of a concept for what may prove to be an alternative approach in elementary particle physics. An attempt is made to accommodate on physical grounds an intuitive awareness that the natural world is essentially a continuum. For the purposes of this model light, or rather electromagnetic radiation in the more general sense of the term, is regarded as the building material of matter, and of leptons in particular.

2. An electromagnetic (relativistic) approach of the Schrödinger wave equation.

The model assumes electromagnetic radiation in a perfect vacuum. Rather than working with the electric field intensity $\overrightarrow{E}$ and the magnetic induction $\overrightarrow{B}$ directly, it is usually more convenient to work in terms of the potentials. The scalar potential φ and the vector potential $\overrightarrow{A}$ are defined by

$$\overrightarrow{E} = -\overrightarrow{\text{grad}}\,\varphi - \frac{\partial \overrightarrow{A}}{\partial t} \tag{1}$$

$$\overrightarrow{B} = \mathbf{curl}\,\overrightarrow{A} \tag{2}$$

If the 4-potential [Ref.(15)] is defined by

$$\varphi_a = (\frac{i\varphi}{c}, \overrightarrow{A}) \tag{3}$$

then the electromagnetic field tensor or the Maxwell tensor [Ref. (15)] is defined by

$$F_{ab} = \partial_b \varphi_a - \partial_a \varphi_b \tag{4}$$

in which a, b assume the values $0, 1, 2, 3$ respectively where ict is the 0-component. Introducing the current density or source 4-vector j_a by

$$j_a = (icp, \overrightarrow{j}) \tag{5}$$

the Maxwell equations in relativistic units ($c = 1$ and $G = 1$ is used in the equations 6, 7, and 8) can be written in the form

$$\partial_b F_{ab} = j_a \tag{6}$$

$$\partial_a F_{bc} + \partial_c F_{ab} + \partial_b F_{ca} = 0 \tag{7}$$

The Maxwell energy-momentum tensor T_{ab} [Ref.(24)] is

$$T_{ab} = \frac{1}{4\pi}(g^{cd} F_{ac} F_{db} + \frac{1}{4} g_{ab} F_{cd} F^{cd}) \tag{8}$$

in source-free regions. In Euclidian space the metric tensor

$$g_{ab} = \delta_{ab} \tag{9}$$

which means in general relativity the absence of a space-time curvature, caused by mass or its equivalence energy. The equivalence of mass and energy in special relativity assumes all forms of energy will act as sources for the gravitational field, which is expressed by (10). The Einstein tensor G_{ab} has proved to be proportional to the Maxwell energy-momentum tensor [Ref. (24)]

$$G_{ab} = \kappa T_{ab} \tag{10}$$

in which κ is a constant of proportionality called the coupling constant and equal to

$$\kappa = \frac{8\pi G}{c^2} \tag{11}$$

in which "G" is the gravitational constant. Substituting (8) in (10) results in the Einstein-Maxwell equations [Ref.(24)]

$$G_{ab} = \frac{2G}{c^2}(g^{cd} F_{ac} F_{db} + \frac{1}{4} g_{ab} F_{cd} F^{cd}) \tag{12}$$

Up to here the theory is classical and well known. An introduction of a new concept in electromagnetism is done by the introduction of the complex vector wave function denoted by $\overrightarrow{\Phi}(\overrightarrow{x}, t)$ and the conjugated complex vector wave function $\overrightarrow{\Phi}^*(\overrightarrow{x}, t)$, where:

$$\overrightarrow{\Phi}(\overrightarrow{x}, t) = \sqrt{\frac{\epsilon}{2}}(\mathbf{curl}\,\overrightarrow{A}(\overrightarrow{x}, t) - \frac{i}{c}(\overrightarrow{\mathrm{grad}}\,\varphi(\overrightarrow{x}, t) + \frac{\partial \overrightarrow{A}(\overrightarrow{x}, t)}{\partial t})) \tag{13}$$

In this equation, ϵ is the permittivity and c the speed of light. The complex vector functions are chosen such that the scalar product of both vector functions is equal to the relativistic electromagnetic mass density distribution $\rho_{EM}(\overrightarrow{x},t)$ in the electromagnetic wave:

$$\rho_{EM}(\overrightarrow{x},t) = \overrightarrow{\Phi}(\overrightarrow{x},t) \cdot \overrightarrow{\Phi}^*(\overrightarrow{x},t) \tag{14}$$

The transport of electromagnetic energy is determined by the Poynting vector $\overrightarrow{S}(\overrightarrow{x},t)$, which is equal to the cross product of both vector functions multiplied by ic^3:

$$\overrightarrow{S}(\overrightarrow{x},t) = ic^3(\overrightarrow{\Phi}^*(\overrightarrow{x},t)) \times (\overrightarrow{\Phi}(\overrightarrow{x},t)) \tag{15}$$

In the absence of gravity the equations (14) and (15) equal the equations (3-A) and (4-A) in the appendix. To avoid confusion non-relativistic units will be used below. If the model is to have plausible foundations, electromagnetic radiation must possess material properties. Free electromagnetic radiation in no way satisfies this condition. While obeying Maxwell's laws, is does not satisfy the Schrödinger wave equation nor the laws of inertia. (Self-) confined electromagnetic radiation does however possess material properties.

Confined electromagnetic radiation exhibits the property of inertia (Ref.(19) which describes the measured electromagnetic mass of longitudinal photons) and further satisfies, in first-order approximation, the law of inertia as formulated by Newton, subjected to the condition that the dimension of the self-confined radiation is much smaller than $c^2/\ddot{x}$, where $\ddot{x}$ is the modulus of acceleration of the wave packet, which is demonstrated in (78) and the equations (42-A) and (50-A) in the appendix, restricted to the absence of gravity. In order to simplify the calculation of the relativistic effects, the starting-point chosen for this model is a simplified model of external confinement consisting of perfectly reflecting mirrors (with adjustable curvature and negligible mass) within which a monochromatic beam of light is trapped. The mass of this confined electromagnetic wave is not negligible in this model. The monochromatic nature of the confined wave is essential to the entire model. Just as is the case with free electromagnetic radiation, confined radiation satisfies the Lorentz transformations which describe the relativistic effects that arise if an observer moves at a relative velocity "v" with respect to the source of an electromagnetic wave.

$$F'_{ab} = L^a_c F_{cd} L^b_d \tag{16}$$

where a, b, c, d assume the values 0 to 3 respectively. L_a^b is the Lorentz transformation matrix, given e.g. in (57-A) for a transformation due to a relative velocity along the x-axis between observer and field configuration and F_{cd} is the field describing matrix presented in (27-A). In classical quantum mechanics, which is mainly wave mechanics, it is sometimes preferable to consider confined electromagnetic radiation as the superposition of Fourier components propagating in opposite direction. This is illustrated in equation (19-A) in the appendix. It will be clear that superposition of the Lorentz transformations of the Fourier components, propagating in opposite directions, has to be equal to the Lorentz transformation (56-A) in the appendix, which is the usual presentation. This equality e.g. is demonstrated by the Lorentz transformations (59-A) and (61-A) and (41), in which (41) is the result of the Lorentz transformation of the Fourier components, travelling in opposite directions.

In the most reduced example of plane monochromatic radiation, the confined radiation can be described by two plane waves travelling in opposite directions, confined by two perfect reflecting mirrors. When the movement is parallel to the confined beam, the observer simultaneously discerns an increased frequency of the beam propagating towards the observer and a decreased frequency of the beam propagating in opposite direction. The transformation of the beam propagating in the same direction of the observer is indicated as ${}^{-}L_a^b$, while the transformation of the beam moving in opposite direction is indicated by ${}^{+}L_a^b$. The averaged observed frequencies and energies of both beams, propagating in opposite direction, are increased according (10-A) and (11-A) in the appendix, by a factor $+\frac{1}{2}v^2/c^2$ in first order approximation and are proportional to the observed kinetic energy $\frac{1}{2}m_E v^2$ (where $m_E = W/c^2$) of the electromagnetic mass, which is accordingly classical mechanics. This is a characteristic of all kinds of confined radiation.

The Lorentz transformation of confined radiation is described by ${}^{s}L_a^b$ in which "s" differs in sign due to the described part of the confined wave [Ref.(9)]. The corresponding tensor ${}^{s}F_{cd}$ consists of a part ${}^{-}F_{cd}$ describing the waves propagating in the same direction as the observer and a part ${}^{+}F_{cd}$ describing the waves propagating in opposite direction. The corresponding tensor F_{cd} transforms like:

$$F'_{ab} = {}^{+}L_c^{a+}F_{cd}{}^{+}L_d^b +^{-} L_c^{a-}F_{cd}^{-}L_d^b \tag{17}$$

The Lorentz transformation (17) is identical to (16) but offers some advantages. A very simplified example of this concept is demonstrated in the appendix in the equations (9-A), (16-A) and (19-A). Making use of this basic principle, confined monochromatic radiation presents inertia (78) and proofs to obey Planck's law (20) and in a mode of self confinement the Schrödinger wave equation (56). Deriving Planck's law for confined radiation is made under the assumption that the Lorentz transformation is valid in (slow) or non-accelerated movements. In that case one can consider a confined electromagnetic field, e.g. monochromatic radiation with frequency f_0 and energy W_0 confined between two perfect reflecting mirrors, which is compressed by moving one of both mirrors slowly to the other in order that no kinetic energy of the confined electromagnetic mass is introduced.

Moving both mirrors to each other with a constant velocity "v", means that work has to be done to counterbalance the radiation pressure, given in (48-A) and (51-A), which equals $\frac{1}{2}w$ and in which w is the energy density of the confined radiation, while simultaneously a rise in frequency occurs due to the Doppler shift. The distance between both mirrors is "l" and their surface "Λ". The time Δt equals $2l/c$ which again the reflected light requires to reach the moving reflecting mirror. During the time Δt work ΔW has done equal to:

$$\Delta W = \frac{1}{2} w \Lambda \nu \Delta t = \frac{w \Lambda \nu l}{c} = \frac{\nu W_O}{c} \tag{18}$$

During the same interval Δt the incident wave on the moving mirror is reflected with an increased frequency due to the Doppler shift, given by (10-A), and equals:

$$f' = f_0 + \Delta f = \gamma(1 + \frac{\nu}{c}) f_0 \tag{19}$$

At low compression velocity γ is nearly 1. Combining (18) and (19) results in:

$$\Delta W = \frac{W_0}{f_0} \Delta f \tag{20}$$

The term Δf is the frequency shift after one complete reflection between both mirrors. Continuing the compression, the frequency shift also continues by discrete steps Δf after each reflection of the moving mirror. This compression method e.g. has been applied in coupled high power pulse lasers in which light intensities of $100[GW]$ in the $U.V.$ region nowadays can be reached.

There is no theoretical limit for a maximum frequency or energy density, only a practical one. Mirrors are not able to compress the confined radiation to frequencies comparable with frequencies corresponding to elementary particles and an energy density desired for self- confinement. Only in phenomena like black holes the desired compression forces may occur.

The constant W_0/f_0 is indicated as h_E and is comparable with Planck's constant. The ratio W_0/f_0 is independent of the velocity "v" of the moving mirror, which implies that independent of the velocity of compression, the frequency of confined radiation increases proportionally to the energy of the system. For a monochromatic system of confinement of radiation with homogeneous energy density, linear integration of (20) results in (21). Introducing a system of asymptotic infinite cubes with asymptotic infinite small sizes, all confining radiation of different energy density, leads to a more general law (21) for confined radiation with an arbitrary energy density, derived by integrating (20) over an arbitrary volume of (self-) confined radiation.

$$W = h_E f \tag{21}$$

where "W" is the total (self-) confined electromagnetic energy, and "f" is the frequency of the (self-) confined monochromatic wave. Where external interaction occurs, "W" and "f" change, but the ratio of the two remains h_E, which is determined by the initial conditions of confinement. In the provisional system of mirrors involving external confinement, h_E is a constant which depends on the initial energy and frequency of the system. In a system of self-confinement the frequency and wavelength are determined by the dimension of the confinement and the total energy defines the dimension. In that circumstance h_E becomes a physical constant.

Because the moving mirror straight transforms mechanical energy (counter-balancing the radiation pressure) into electromagnetic energy (the beam reflected by the moving mirror has as well an increased frequency as an increased energy density, according the Lorentz transformation (17), with a corresponding electromagnetic mass, the moving mirror is an interesting example of an energy - mass transformer. Compression of confined radiation results straight in an increase of mass and by (17), (18) and (20) and satisfying Einstein's equation $W = mc^2$ (78), the system becomes heavier in a gravitational field. Decompression of the confined radiation results in a reverse transformation. The same mass-energy transformation occurs during (de-) compression of any arbitrary kind of confinement of electromagnetic radiation, including self-confinement.

In circumstances of self-confinement, electromagnetic radiation satisfies the Schrödinger wave equation (56) when energy densities are sufficiently high [Ref.(24)](of the order of $10^{73}[J/m^3]$). For this purpose, the starting point chosen is the model of external radiation confinement within a system of perfectly reflecting mirrors, after which the aspect of (gravitational or electro-magneto-static) self-confinement is introduced at a later stage. The mirror system has been chosen such that a vibration mode of electromagnetic radiation with frequency ω_0 satisfies the consequent boundary conditions. In this example, if the system of mirrors is at rest with respect to an observer, an electric field vector is measured which is equal to:

$$\begin{aligned}\overrightarrow{E}(\overrightarrow{x},t) &= -\frac{ic(\overrightarrow{\Phi}-\overrightarrow{\Phi}^*)}{\sqrt{2\epsilon}}\\ &= \frac{-\overrightarrow{E}_O}{4}\int(e^{i\omega t}-e^{-i\omega t})(e^{i\overrightarrow{k}\cdot\overrightarrow{x}}-e^{-i\overrightarrow{k}\cdot\overrightarrow{x}})\delta(\omega_O)d\omega\end{aligned} \tag{22}$$

and in which E_0 is the amplitude of the electrical field intensity. The magnetic field vector observed is equal to:

$$\begin{aligned}\overrightarrow{H}(\overrightarrow{x},t) &= \frac{(\overrightarrow{\Phi}+\overrightarrow{\Phi}^*)}{\mu\sqrt{2\epsilon}}\\ &= \frac{\overrightarrow{e}_s\times\overrightarrow{E}_O}{\sqrt{\frac{2\mu}{\epsilon}}}\int(e^{i\omega t}+e^{-i\omega t})(e^{i\overrightarrow{k}\cdot\overrightarrow{x}}+e^{-i\overrightarrow{k}\cdot\overrightarrow{x}})\delta(\omega_O)d\omega\end{aligned} \tag{23}$$

where $\overrightarrow{e}_s$ is the unit vector in the direction of wave propagation and μ the permeability. The electric and magnetic field intensities (22) and (23) are measured by an observer at rest with respect to the system of mirrors. An observer, moving relative to the mirror's coordinate system discerns a transformed electric and magnetic field intensity, frequency and wavelength. Introducing the 4-wave vector:

$$k_a = (\frac{i\omega}{c},\overrightarrow{k}) \tag{24}$$

the transformed frequency and wavelength are presented by:

$$^s k'_a = {}^+L_b^{a+}k_b + {}^- L_b^{a-}k_b \tag{25}$$

which 1-dimensional transformation is given in (12-A) and (13-A).

Defining the Lorentz contraction term γ:

$$\gamma = \sqrt{1 - \frac{\vec{v}_G \cdot \vec{v}_G}{c^2}} \tag{26}$$

in which $\vec{v}_G$ is the velocity of the observer relative to the coordinate system of the confining mirrors. Using (17), (22), (25) and (26), the transformed electric field intensity is presented by:

$$\vec{E}'(x',t') = \gamma[\vec{E}_O \sin(\beta)\sin(\alpha) + \frac{\vec{v}_G \times \vec{e}_s \times \vec{E}_O}{c}\cos(\beta)\cos(\alpha)] \tag{27}$$

The phase β is given by:

$$\beta = \gamma[\omega_O t' + \frac{(\vec{v}_G \cdot \vec{e}_s)(\vec{k} \cdot \vec{x}')}{c}] \tag{28}$$

where ω_0 is the non-transformed frequency, mostly indicated as rest frequency. Phase α is given by:

$$\alpha = \gamma[\vec{k} \cdot \vec{x}' + \frac{(\vec{v}_G \cdot \vec{e}_s)\omega_O t'}{c}] \tag{29}$$

This result is also demonstrated in a 1-dimensional example in the appendix in the equations (19-A) and (20-A). Phases β and α in (28) and (29) are Lorentz invariant parameters, which follows from the reverse-transformation of the observer's coordinates ($\sum'$) to the confined wave packet's own system variables ($\sum$), presented in the 1-dimensional example in (25-A) and (26-A). The observer in ($\sum'$) measures an electromagnetic wave with an apparent phase velocity $\vec{v}_\beta$ which is determined by (28):

$$\vec{v}_\beta \cdot \vec{v}_G = c^2 \tag{30}$$

which equation is comparable with (22-A) in the appendix. From (30) it follows that the phase velocity of a confined electromagnetic wave packet travelling at a velocity $\vec{v}_G$ with respect to an observer is always measured by the latter as greater than the velocity of light as a result of the relativistic transformations (17) and (25). This is accordingly the phase velocity of quantum mechanical probability waves describing elementary particles. Because the phase velocity is not related to the velocity of transport of information or energy and mass, (30) does not contradict the principle of relativity. Phase β in (28) represents a relativistically transformed wavelength λ (in the direction of propagation of the wave packet) which is measured by a stationary observer in the coordinate system ($\sum'$) with respect to which a confined electromagnetic monochromatic wave packet moves at a velocity $\overrightarrow{\nu}_G$, yielding:

$$\lambda = \frac{2\pi c}{\gamma \overrightarrow{k} \cdot \overrightarrow{\nu}_G} \tag{31}$$

Combining the Einstein relation $W_0 = m_0 c^2$, where W_0 is the rest energy and m_0 is the rest mass, with (21) and the fact that the modulus of the wave vector $\overrightarrow{k}$ is equal to ω/c, there follows from (31) a relation for the observed relativistic 4-wavelength λ_a [Ref. (21)]:

$$\lambda_a = \frac{h_E}{p_a} \tag{32}$$

which equation is equal to (24-A) for $a = 1$. In (32) λ_a is the observed wavelength in coordinate direction a, the zero component $\lambda_0 = -icT$, is the time component of the wavelength and h_E is the constant defined in (21). The term p_a is the relativistic momentum 4-vector of the confined electromagnetic monochromatic wave and is equal to the product of the relativistic mass $\gamma W_0/c^2$ and the 4-vector velocity $(ic, \overrightarrow{\nu}_G)$. Relation (32) represents the observed relativistic effect of a confined electromagnetic monochromatic wave, derived from (17) and (25) and shows a characteristic correspondence to quantum mechanical probability waves [Ref. (14)], describing elementary particles.

The force, operating on confined electromagnetic radiation, can be derived from the tension tensor $\overline{\overline{t}}$ which is a sub-tensor in (49-A), and the force equation (48-A). The momentum 4-vector is defined by:

$$p^a = (\frac{iW}{c}, \overrightarrow{P}) \tag{33}$$

The transformed potential 4-vector is presented by:

$$^{s}\varphi'_a = {}^{+}L^{a+}_{b}\varphi_b + {}^{-}L^{a-}_{b}\varphi_b \tag{34}$$

Using (3), (13) and (34), the transformed vector wave function $\vec{\phi}'(\vec{x}',t')$ is presented by:

$$\vec{\Phi}'(\vec{x}',t) = \sqrt{\frac{\epsilon}{2}}[\mathbf{curl}\,\vec{A}'(\vec{x}',t') - \frac{i}{c}[\overrightarrow{\text{grad}}\,\varphi'(\vec{x}',t') + \frac{\partial \vec{A}'(\vec{x}',t')}{\partial t'}]] \tag{35}$$

Making use of (14) and (15), the pseudo Poynting 4-vector, which equals icT^{a0} (presented in the appendix in 51A and related to the example in figure 1), is defined by:

$$S^a = (ic(w_d + w_s), \vec{S}) = ic^3[(\vec{\Phi}^*(\vec{x},t)\cdot\vec{\Phi}(\vec{x},t)), (\vec{\Phi}(\vec{x},t)\times\Phi^*(\vec{x},t))] \tag{36}$$

The energy density w_d describes the dynamic radiation part of the confined electromagnetic phenomena, excluding the mostly static energy part w_s confining the system. The transformed Poynting 4-vector is presented by:

$$S^{a'} = (ic(w_d' + w_s'), \vec{S}') = ic^3[(\vec{\Phi}^{*'}\cdot\vec{\Phi}'), (\vec{\Phi}'\times\vec{\Phi}^{*'})] \tag{37}$$

Only under the condition that the energy density is built up of the dynamic part and the confining static part, the Poynting pseudo 4-vector in (37) transforms like a real 4-vector with Lorentz invariant modulus. Substituting (35) in (37), and using (34), this results in an alternative notation for the transformation of the Poynting 4-vector:

$$^{s}S_a' = {}^{+}L_b^{a\,+}S_b + {}^{-}L_b^{a\,-}S_b \tag{38}$$

The transformation (38) is for confined radiation in perfect balance identical to the transformation (56-A) for the index "$d = 0$" in the appendix. The momentum 4-vector of the confined radiation can be determined with the Poynting 4-vector (36) by (50-A), which equals:

$$p^a = \frac{i}{c}\int_{volume} T^{a0}dV = \frac{1}{c^2}\int_{volume} S^a dV \tag{39}$$

The momentum 4-vector for confined electromagnetic radiation is related by (39) to the Poynting 4-vector of the electromagnetic system. The introduction of a Poynting pseudo 4-vector for confined electromagnetic phenomena and its relation to the momentum 4-vector, given by

(39), is an aspect in classical electromagnetism that relates in an important way classical mechanics to quantum mechanics. This relation is an elementary contribution to the particle-like property of confined radiation which implies that confined monochromatic radiation obeys the Schrödinger wave equation. It is important to notice that only because the Poynting pseudo 4-vector in (38) obeys the Lorentz transformation, the continuity equation can be written as a Schrödinger equation for confined electromagnetic radiation. Making use of (38) and (39) the transformation of the momentum 4-vector for confined radiation is represented by:

$$P'_a = L^a_b P_b \tag{40}$$

Equation (40) offers an important result. Electro-Magnetic Confinements (EMC) or Electro-Magnetic Self confinements (EMS) appear to transform identically to elementary particles. This means that EMS offer a realistic alternative for a model of matter described by elementary particles. However it is also important to realize that many questions are still not answered. Only the conclusion has been made that if the result of (40) would be that EMS does not obey (40), that EMS does not transform perfectly identically to elementary particles and the whole idea of matter, consisting of EMS, would be without any value.

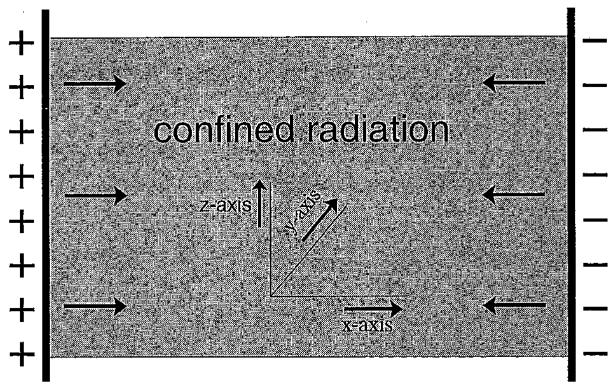

Figure 1.

Formula (37) and (38) are determined by calculating the Poynting 4-vector of perfect confined electromagnetic radiation. In the case of Lorentz invariant transformations of the Poynting 4-vector modulus, the parameter of a system in equilibrium must be transformed. In the model of external radiation confinement by a system of mirrors (figure 1), this is e.g. achieved by applying an opposite electric charge on a pair of mirrors which compensates for the radiation pressure between the two massless mirrors facing each other. If the distance between the two mirrors decreases slightly, the radiation pressure as well as the frequency increases [equations (18) and (19)] and the repulsive radiation pressure overcomes the attractive electrostatic force and vice versa. In this way the dynamic system is stable.

The Poynting vector and the energy density of the dynamic field with frequency ω are denoted by S_D and w_D, respectively, and for the static field, which compensates for the repulsive radiation pressure on the two mirrors, these two parameters are denoted by S_S and w_S, respectively. It is important to realize that the confined dynamic field with frequency ω transforms differently from the (static) field describing the confining system itself due to the different orientation of the fields relative to the moving observer.

A dynamic Poynting pseudo 4-vector, describing the frequency- dependent part of the pseudo Poynting 4-vector, can be assigned to a monochromatic electromagnetic wave packet, externally confined in a system of mirrors and represented in its simplest form in (22) and (23). The transformation of the Poynting pseudo 4-vector can be performed more easily by using a notation reported earlier by Pauli [Ref. (11)], which split up the confined monochromatic wave in perfect symmetric parts related to the ^+L and ^-L transformations. Using the Pauli notation and (38), the transformed Poynting 4-vector is represented by:

$$(\vec{S}'_d + \vec{S}'_s) + i(w'_d + w'_s)c = \\ \gamma^2\Big[(1 + \frac{\vec{v}_G \cdot \vec{v}_G}{c^2})\vec{S}_d + \frac{\vec{S}_S}{\gamma^2} - 2\vec{v}_G w_d \\ + ic\big((1 + \frac{\vec{v}_G \cdot \vec{v}_G}{c^2})w_d + \frac{w_s}{\gamma^2} - \frac{2\vec{v}_G \cdot \vec{S}_d}{c^2}\big)\Big] \tag{41}$$

which result is also in a more classical way obtained from the transformation of the energy-momentum tensor (56-A), demonstrated in (59-A) and (61-A), in the appendix.

The relativistic notation (41) for the Poynting 4-vector of a monochromatic electromagnetic wave packet leads to a relativistic equation, which demonstrates a remarkable correspondence with the Schrödinger, Klein/Gordon and Dirac equations. The derivation for the Klein/Gordon equation is essentially based on the equations (38) and (39), to which the wavelike nature is introduced later by applying (32). For this reason the Klein/Gordon equation also gives solutions for negative energy. The Dirac equation (102) corresponds with the Schrödinger wave equation at non-relativistic velocities. This is not in contradiction with the relativistic origin of (41) because it is a well known aspect that relativity is demonstrated most significantly at non relativistic velocities. For example the phenomenon of mass, which is a pure relativistic effect of energy, is demonstrated most significantly at rest on a scale or at non relativistic velocities by its inertia. At relativistic velocities momentum and energy, or its equivalence mass, are less easier to separate. In this chapter the results of (41) are considered, restricted to electromagnetic confinements at non relativistic velocities relative to the observer, and for that reason may only result in a Schrödinger-like wave equation.

The Schrödinger wave equation for (self-) confined electromagnetic radiation will be derived from the law of continuity below. The law of continuity for electromagnetic radiation, generally termed Poynting's theorem and given in the appendix (63-A), which describes the law of conservation of electromagnetic energy, is presented in the observer's system of coordinates in vacuum by:

$$\nabla' \cdot \vec{S}'(\vec{x}', t') = -\frac{\partial w'(\vec{x}', t')}{\partial t'} \tag{42}$$

In this equation $\vec{S}'(\vec{x}', t')$ is Poynting's vector and $w'(\vec{x}', t)$ the electromagnetic energy density observed in the coordinate system of the observer. In the case of non-relativistic velocities, substitution of (41) in (42) results in two equations in which the momentum and the energy, derived from the Poynting 4-vector, can be regarded as separate variables.

$$\frac{1}{2} \cdot \nabla' \cdot (\vec{S}_d + \vec{S}_s) + \frac{\nu_G^2}{2c^2} \nabla' \cdot (\vec{S}_d - \vec{S}_s) = -\frac{1}{c^2} \frac{\partial(\vec{\nu}_G \cdot \vec{S}_d)}{\partial t'} \tag{43}$$

$$\nabla' \cdot (\vec{\nu}_G w_d) = -\frac{1}{2} \frac{\partial w_d + w_s)}{\partial t'} - \frac{\vec{\nu}_G \cdot \vec{\nu}_G}{2c^2} \frac{\partial(w_d - w_s)}{\partial t'} \tag{44}$$

In the case of non-relativistic velocities, equation (43) can be regarded as a momentum density equation and (44) as an energy density equation. In the case of relativistic velocities splitting (43) and (44) from (42) is only permitted under restricted conditions. At non-relativistic velocities under certain conditions, equation (44) changes into the conventional Schrödinger equation for (self-) confined electromagnetic radiation. Bosons, described by symmetric wave functions, as well as fermions, described by anti-symmetric wave functions, obey the Schrödinger wave equation. It is well known that electromagnetic phenomena can be described in terms of photons which belong to the boson group. A transition from bosons to fermions is not allowed in classical quantum mechanics. In a two particle problem bosons are described by a symmetric-wave function, in which the positions of the particles 1 and 2 are represented by the vectors $\vec{r}_1$ and $\vec{r}_2$ respectively:

$$\Psi(\vec{r}_1, \vec{r}_2) = \Psi(\vec{r}_2, \vec{r}_1) \tag{45}$$

Fermions are described by an anti-symmetric wave function which is represented in a two particle problem as:

$$\Psi(\vec{r}_1, \vec{r}_2) = -\Psi(\vec{r}_2, \vec{r}_1) \tag{46}$$

Because free electromagnetic waves are described by bosons, it would be a reasonable assumption that Electro-Magnetic (Self) confinements (EMS) behave like bosons. This contradicts however (44) which describes boson- as well as fermion-like behaviour. By exchanging two particles, described by EMS, the relative velocities between the observer and the particles may change in sign which is observed as a change in sign of the wave function, because the left of (44) only represents the relativistic part of the Poynting vector. The Lorentz matrices ${}^{+}L$ and ${}^{-}L$ exchange.

A very simplified example, not describing EMS but free electromagnetic radiation, will possible partly illustrate this effect. Two spherical emitting point lasers with frequencies ω_1 and ω_2 are at rest in a coordinate system. An observer is moving from laser 1 to laser 2 and is for that reason observing the interference pattern of the frequencies $\omega_1 - \Delta\omega_1$ and $\omega_2 + \Delta\omega_2$. Exchanging both laser sources results in an observed interference pattern $\omega_1 + \Delta\omega_1$ and $\omega_2 - \Delta\omega_2$. An equation containing only the relativistic part $\Delta\omega_2 - \Delta\omega_1$ will after exchanging the particles contain the opposite terms. The same effect occurs with the observed amplitudes φ_a and the relativistic parts $\Delta\varphi_a$ of the emitted beams. Observing only the relativistic parts $\Delta\omega$ and $\Delta\varphi_a$, exchanging the particles will be observed as a change in sign from $\Delta\omega$ and $\Delta\varphi_a$. Because the left side of (44) describes only the relativistic part of the phenomena, described by

$\Delta\omega$ and $\Delta\varphi_a$, a change in sign is possible by exchanging and EMS can, dependent of the way of confinement, represent fermion like behaviour.

It is important to notice that (44) is not describing the electromagnetic wave itself but only relativistic effects of it. Effectively this equation describes the transformation of energy into momentum and reverse due to relativistic effects. This implies that in this model not the correspondence is suggested between electromagnetic waves and probability waves but a correspondence is suggested between the relativistic effects of confined electromagnetic waves and quantum mechanical probability waves. In this way not a transition of bosons into fermions is suggested, but due to the relativistic effects of EMS in special confinements fermion like behaviour may occur. Wave functions which satisfy (44) propagate at the velocity of light. In the case of a confined monochromatic electromagnetic wave packet with frequency ω the observed wavelength is, by definition, $2\pi c/\omega$. This contradicts the observed probability waves in quantum mechanics where the observed wavelength is momentum-dependent.

A possible way to explain this observed phenomenon in terms of electromagnetism is to introduce the energy density $\tilde{w}_d(\vec{x}, t)$ spatially averaged across a wavelength. From now on this averaging will be described as averaging across a microcube with the dimensions of the wavelength $2\pi c/\omega$ of the confined monochromatic radiation. The energy density is not averaged over time because the phase information β in (27) and (28) is not lost.

The phase β, as shown in (32), gives the relation between the observed wavelength and the momentum. If the integration of the energy density takes place across a microcube, the average energy density remains position-dependent, but with a limited resolution which is determined by the wavelength of the monochromatic electromagnetic wave packet. The actual wavelength $2\pi c/\omega$ of the dynamic energy density w_d has disappeared as a result of integration. A momentum dependent wavelength, given in (27) and (32), remains as a relativistic effect of an electromagnetic wave. The spatial averaging of the energy density across a microcube, introduced above, implies that the Schrödinger wave equation cannot satisfy the requirements at relativistic velocities, for then the wavelength λ in (32) is in the order of magnitude of the wavelength $2\pi c/\omega$, the dimension of the microcube. A wave equation which also remains valid at relativistic velocities can only be derived in this model by substituting (13) in (36) and (41) and the result of this in (42). By analogy with (13) the complex conjugated scalar functions $\Psi(\vec{x}', t')$ and $\Psi^*(\vec{x}', t')$ are introduced, yielding:

$$\tilde{\rho}_{EM}(\vec{x}', t') = \Psi(\vec{x}', t')\Psi^*(\vec{x}', t') \tag{47}$$

where $\tilde{\rho}_{EM}(\vec{x}', t')$, just as in (14), is the averaged electromagnetic relativistic mass density. The function $\Psi(\vec{x}', t')$, by definition, is complex and satisfies:

$$\Psi(\vec{x}', t') = \sqrt{\frac{\epsilon}{2}}(\tilde{B}(\vec{x}', t') + \frac{i\tilde{E}(\vec{x}', t')}{c}) \tag{48}$$

in which $\tilde{B}(\vec{x}', t')$ and $\tilde{E}(\vec{x}', t')$ are the effective values of the modulus of the magnetic induction and the electric field intensity, respectively, calculated across a microcube with the dimensions of half a wavelength. In the special case of the effective electric and magnetic field intensities, calculated across a microcube, the position and time-dependence of the function $\Psi(\vec{x}', t')$ can be defined for a monochromatic electromagnetic wave packet with frequency ω_0 with the aid of (22), (23), (27), (28) and (48) as follows:

$$\Psi(\vec{x}', t') = \tilde{\Psi}_R(\vec{x}', t') \cdot e^{i\beta} \tag{49}$$

In (49) the function $\Psi(\vec{x}', t')$ is represented by the product of a real function, denoted by $\tilde{\Psi}_R(\vec{x}', t')$, which is equal to the root of the electromagnetic mass density averaged across a microcube with the dimension of the wavelength λ, and the term $e^{i\beta}$ which, if the confined electromagnetic wave is at rest with respect to the observer, is only determined by the fundamental frequency ω_0 of the confined wave. Subject to the condition of non-relativistic velocities and the assumption that the confined radiation energy density with frequency ω averaged across a microcube is equal to the static energy density of confinement, using the Einstein relation, averaged over a microcube, $\tilde{w} = \tilde{\rho}_{EM}c^2$ and substitution of (47) in (44) results in:

$$\Psi^*\nabla' \cdot (\vec{v}_G\Psi) + (\Psi\vec{v}_G) \cdot \nabla'\Psi^* = -\Psi\frac{\partial\Psi^*}{\partial t'} - \Psi^*\frac{\partial\Psi}{\partial t'} \tag{50}$$

For a confined monochromatic electromagnetic wave with a rest frequency ω_0 travelling at a velocity $\vec{v}_G$ with respect to the observer and using (49) and (28) we have:

$$\nabla'\Psi(\vec{x}', t') = e^{i\beta}\nabla'\tilde{\Psi}_R(\vec{x}', t') + \frac{i\gamma\omega\vec{v}_G}{c^2}\Psi(\vec{x}', t') \tag{51}$$

Substitution of (51) in (50) results in:

$$\frac{c^2}{i\gamma\omega}\nabla'^2\Psi - \frac{c^2 e^{i\beta}}{i\gamma\omega}\nabla'^2\tilde{\Psi}_R - 2i\gamma\omega(1+\frac{\nu_G^2}{2c^2})\Psi = -2\frac{\partial\Psi}{\partial t'} \tag{52}$$

Using Einstein's relation $W = m_E c^2 = \hbar_E \omega$ with $\hbar = h_E/2\pi$, in which h_E is introduced into equation (21) and ω_0 is the rest frequency of the confined electromagnetic wave, (52) becomes:

$$-\frac{\hbar_E^2}{2m_E}\nabla'^2\Psi + \frac{\hbar_E^2 e^{i\beta}}{2m_E}\nabla'^2\tilde{\Psi}_R - m_E c^2(1+\frac{\nu_G^2}{2c^2})\Psi = i\hbar_E\frac{\partial\Psi}{\partial t'} \tag{53}$$

Here m_E is the relativistic mass of the confined electromagnetic energy and is equal to γm_0, where m_0 is the rest mass of the confined electromagnetic field energy. The term $m_E c^2$ is the internal energy V_0 of the confined electromagnetic radiation. The change of the external potential energy V_{PE} in an external force field is equal to the opposite change in the kinetic energy $1/2 m_E V_G^2$. Applying this in (53) results in:

$$-\frac{\hbar_E^2}{2m_E}\nabla'^2\Psi + \frac{\hbar_E^2 e^{i\beta}}{2m_E}\nabla'^2\tilde{\Psi}_R - V_0\Psi + V_{PE}\Psi = i\hbar_E\frac{\partial\Psi}{\partial t'} \tag{54}$$

To reduce (54) to a Schrödinger-type wave equation, a self-confinement of the electromagnetic radiation is assumed in this model. This self-confinement can occur in several ways. A basic model assumes a self-confinement of electromagnetic radiation by gravitational waves generated by the electromagnetic energy itself [Ref. (24)].

In the case of a gravitational confinement (or an electro-magneto static confinement which has to fulfil the same conditions) it is assumed that, according to the basic principle of general relativity, any arbitrary energy "W" also represents a mass "m", which generates a gravitational field. In general relativity this effect is indicated by the coupling constant κ in (11). Comparable with general relativity, a confined electromagnetic energy W generates a gravitational field in a manner comparable to a material mass "m" $= W/c^2$. In the case of gravitational self-confinement (or electro-magneto static confinement), in this model the second term in (54) represents the internal potential energy V_{PI} which occurs as a result of the interaction between gravitational confining forces and electromagnetic repulsive forces, given in (116). It follows from (116) that the second term in (54) vanishes at equilibrium. When the gravitational confining forces are in equilibrium with the repulsive electromagnetic radiation forces, the second term in (54) equals zero and (54) changes into:

$$-\frac{\hbar_E^2}{2m_E}\nabla'^2\Psi - V_0\Psi + V_{PE}\Psi = i\hbar_E\frac{\partial\Psi}{\partial t'} \tag{55}$$

In the event of interaction with the surroundings the second term in (54) represents the internal potential energy V_{PI} and (54) changes to:

$$-\frac{\hbar_E^2}{2m_E}\nabla'^2\Psi + V_{PI}\Psi - V_0\Psi + V_{PE}\Psi = i\hbar_E\frac{\partial\Psi}{\partial t'} \tag{56}$$

Equation (56) demonstrates that at non relativistic velocities, so that the energy and the momentum are observed as separated quantities, this equation is a special notation for (64-A) in the appendix in which circumstance the Schrödinger equation controls the energy domain.

Due to the length, this article is split up into 3 sections. Section 2 will be published in the next edition and describes the relativistic correspondence between the electromagnetic Maxwell equations and the quantum mechanical (relativistic) Dirac equation. In section 3 the theoretical possibility of Gravitational Electromagnetic Entities (GEONS) [Ref. (24)] or Electro-magneto-statically confined Electromagnetic entities (EEONS) will be discussed.

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