EXTRACTION OF ENERGY FROM THE VACUUM IN SED: THEORETICAL AND TECHNOLOGICAL MODELS AND LIMITATIONS

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The paper presents an original perspective on how QED and SED models the physical vacuum. We modelled a charged particle as a two-dimensional oscillator and show that the electrostatic interaction between two charged particles represents the effect of the interaction of the two particles with the CZPF background. This model allow estimating the power scattered by electrons and a hydrogen atom supports the conclusion that fundamental particles and atoms are the simplest systems that extract energy from the vacuum. We conclude the power scattered by all electrons generates by redistribution the CZPF background. This conclusion extends theoretical models to explain certain technological applications.

Keywords: physical vacuum, Quantum electrodynamics (QED), Stochastic electrodynamics (SED), Zero Point Field (ZPF), vacuum energy, Classical Zero Point Field (CZPF), Zero-Point Energy extraction, charged particle model.

1. Introduction

The issue of this paper is based on the fields of Quantum Electrodynamics (QED) and Stochastic Electrodynamics (SED), and on the technological field of electrical engineering and nanotechnology.

In quantum electrodynamics (QED) zero-point energy (ZPE) (also known as ground state energy or even as zero-point field) refers to the fundamental energy (in fact the minimum energy) of the quantum oscillators. In quantum physics, any field is modeled as a system of oscillators. According to the Heisenberg's uncertainty principle, the minimum energy of an oscillator is non-zero. Based upon this reason a system of oscillators in a state where the temperature tends to zero Kelvin has a minimum energy, namely the fundamental/ground state energy. According to QED, the physical vacuum, meaning the area in space from which we removed any particles (be it bosons or fermions) is a physical system that has its own energy which has a non-zero

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energy density [1]. At quantum level any field can be associated with a system of particles. From this point of view the associated field of the minimum energy state is called the zero-point field (ZPF). The minimum energy of each quantum oscillator is $\varepsilon = \hbar\omega/2$ (where ω is the oscillator's angular frequency).

The physical vacuum is modelled as a system of electromagnetic oscillators having the angular frequency $\omega \in [0, \infty)$. A free electromagnetic field is quantifiable as a system of oscillators (the photons are particles without a rest mass) its energy density being proportional with the density of photons. This is the fundamental model.

Because the photons can have whatever angular frequency, the existence of some photons having the same energy as a particle-antiparticle pair - namely the vacuum polarization [2] having a rest mass of m ($\hbar\omega = 2mc^2$) - leads to its appearance and then, in a very short amount of time, to its annihilation. That time being very short, the actual measuring devices cannot properly detect it. That is why both the photons and those pairs are considered virtual - they can only manifest themselves, thus becoming real, consequently detectable by the measuring devices. From this point of view, the physical vacuum can also be shaped as a particle-antiparticle plasma. The higher the mass of the pair, the lower the probability of generating a pair. The pairs with the lowest mass have high particle density. That is the reason why this plasma of virtual pairs can be approximated with a plasma of electron-positron pairs, this one having the lowest mass. Analyzing the more general problem of modeling particles as quantums of fields, G. Jaeger, in the paper: *Are Virtual Particles Less Real?* [3], concludes that the classification of particles as virtual and real is incorrect and that virtual particles are real as other quantum particles. It follows that it is irrelevant ontological distinction between virtual particles and other particles.

In the stochastic electrodynamics (Stochastic Electrodynamics - SED) the physical vacuum is shaped as a field of electromagnetic waves (this is the classical model - unquantified system) with random phases (i.e. stochastic field) according to an electromagnetic radiation background having a zero Kelvin (0K) temperature [5]. That is why it was denoted as Classical Zero-point energy (CZPE) or Classical Zero-Point Field – CZPF [4, 5, 6].

Any source, such as a charged particle, is in continuous interaction both with this stochastic field and the electromagnetic radiation that comes from other particles in the Universe. This field is considered real because while interacting with those particles, quantifiable effects are produced. The first measurable effect is the electrostatic interaction between two charges in relative rest, meaning the Coulomb force [7]. From this perspective, the electrical charge can be defined as the property of a physical system to extract energy out of the physical vacuum. The existence of the stationary states is an observable (measurable) effect. The consequence of this effect is the formation of the stable atoms and of the molecules [8, 9, 10]. Another observable phenomenon is the Casimir effect [11, 12], namely the interaction phenomenon between two material plates, regardless the nature of the material and the shape of the plates.

The technological field of electrical engineering and nanotechnology is found in the paper by looking for practical solutions for extracting ZPE, applicable in technology. The aim is to concretize the theory by finding solutions that can provide viable ways to generate electricity in an efficient way and with minimal pollution. It is known that at present the primary energy sources of mankind are in a proportion of over 92%, the same as 150 years ago, the novelties being nuclear energy, solar energy and several other forms of renewable energy, whose share of the total energy produced in the world is less than 0.1%, and the principles and technologies of conversion are unchanged.

There are currently more and more studies on zero point energy (ZPE) and zero point field (ZPF). However, there is no full consensus among scientists on whether ZPF is a real field or just a hypothetical one. Also under the sign of uncertainty is the possibility of extracting and using ZPE in concrete technological applications [13]. Most researchers believe that it is not possible to extract this enormous energy so that it can be used in practical applications.

In the paper, in the applicative part, we demonstrate that the physical vacuum is the cause of all observable phenomena in the Universe and implicitly the source of the existence of fundamental particles and therefore of the interaction energy between particles and implicitly of the energy we can extract, through various devices, from vacuum.

2. Literature review and problem statement

2.1. The ZPF generation in SED and QED

Both in QED and in SED [1-10, 14-19], the spectral energetic density, $\rho(\omega)$, has the same expression:

$$\rho(\omega) = \frac{dw}{d\omega} = \frac{\hbar\omega^3}{2\pi^2 c^3}. \tag{1}$$

In relation (1), w is the volume energy density of ZPF, ω is the angular frequency of the electromagnetic wave, $\hbar$ is the reduced Planck constant ($\hbar = h/2\pi$), c is the speed of the electromagnetic wave in vacuum.

The vacuum's energy density is obtained by integrating (1)

$$w = \int_0^{\omega_M} \rho(\omega) d\omega = \int_0^{\omega_M} \frac{\hbar\omega^3}{2\pi^2 c^3} d\omega = \frac{\hbar\omega_M^4}{8\pi^2 c^3}, w\left(\omega_M \to \infty\right) = \lim_{\omega_M \to \infty} \frac{\hbar\omega_M^4}{8\pi^2 c^3} \to \infty. \tag{2}$$

According to quantum physics, the maximum frequency cannot be infinite but limited to the inverse of Planck time, $t_P = \sqrt{\hbar G/c^5}$ (G is the Newtonian constant of gravitation) so the maximum angular frequency is the one corresponding to Planck mass

$$\omega_M = \omega_P = \sqrt{c^5/\hbar G}. \quad (3)$$

Replacing equation (3) in (2), we have [20-22]:

$$w_M = \frac{\hbar\omega_P^4}{8\pi^2 c^3} = \frac{c^7}{8\pi^2\hbar G^2} \cong 10^{113}\ \mathrm{Jm^{-3}}, \quad (4)$$

which is much higher than the energy density of the Universe.

In SED there are two hypotheses related to the origin and generation of the CZPF background [20, 23]. The first hypothesis refers to the CPZF generation at the beginnings of the Universe (according to Big Bang model) much like the relict equilibrium thermal radiation (cosmic microwave background (CMB)) with the actual temperature of 2.72 K. The second hypothesis considers that the substance in the Universe (namely the existing microsystems in the Universe: free particles, atoms, molecules etc.) dynamically generates CZPF [20, 21, 23].

From the General Relativity point of view, the universe is finite and behaves like an expansion hole, within which the electromagnetic field forms stationary modes. For time being, according to Big Bang theory [22], the temperature of the Universe is 2.72 K. In the cavity of the Universe both thermal modes - namely the equilibrium thermal radiation (the Planck thermal radiation) - and ZPF are formed [20].

Because the equilibrium thermal radiation is of electromagnetic nature, from the quantum point of view it can be modelled like a system of oscillators that, at 0K, has non-zero energy. This equilibrium radiation having a temperature of 0K is exactly ZPE. The spectral density of the radiation in a cavity having a temperature of T is

$$\rho(\omega,T) = \frac{\omega^2}{\pi^2 c^3}\left\{\frac{\hbar\omega}{\exp\left[\hbar\omega/(kT)\right]-1} + \frac{1}{2}\hbar\omega\right\}. \quad (5)$$

If the temperature tends to zero, then (5) becomes (1).

The second model consists in a dynamic ZPF self-generation phenomenon [20, 23, 24]. No matter the model of the Universe, we consider that it is made of several types of macroscopic systems, characterized by the particle density n_i and the cross section of interaction with electromagnetic radiation σ_i, so that the following condition is fulfilled: $n = \sum_i n_i$. We denoted by n the density of particles in the Universe, given a normal distribution.

Let us assume that there is a background electromagnetic radiation of zero temperature, having random phases. Each microsystem interacts with this background and scatters (absorbs and emitting) generating around it a radiation having a Poynting vector $\vec{S}_{0i}$:

$$\vec{S}_{0i}(r) = \frac{c\hat{r}}{4\pi r^2}\int \rho(\omega)\sigma_i(\omega)\, d\omega, \tag{6}$$

in agreement to the simple method introduced in [20].

Considering the sources as points, the contribution of the radiation emitted by $dn_i = n_i dV$ sources, in the point $P(r)$, located at a distance r from the volume element dV, is:

$$\delta S_i = \frac{dV}{4\pi r^2}\int c\rho(\omega) n_i \sigma_i(\omega) d\omega. \tag{7}$$

Considering the contribution of all kind of sources, the elementary Poynting vector becomes:

$$\delta S = \sum_i \delta S_i = dV \sum_i n_i S_{i0} = \frac{dV}{4\pi r^2}\int c\rho(\omega)\sum_i n_i \sigma_i(\omega) d\omega. \tag{8}$$

Then the energy density of the radiation arriving in the point $P(r)$ according to the elementary Poynting vector is:

$$\delta w_P = \delta S_P / c = dV \sum_i \left(n_i S_{i0} / c \right). \tag{9}$$

The total density is obtained integrating on the entire volume, around point $P(r)$. The volume integration depends on the kind of the chosen Universe model.

Puthoff and Wesson [23, 24] analyses the ZPF dynamic generation in case of an expanding Universe having zero curvature. Considering that the scattered power by the protons in the Universe and other systems with higher rest mass is considerable less than the power scattered by the punctual electrons (for a punctual electron the cross section $\sigma_e(\omega) \to \sigma_{Te} = (8\pi/3)\left(e^2/m_e c^2\right)^2$ i.e. the Thomson cross section: $e^2 = q_e^2/(4\pi\varepsilon_0)$ is the square of the charge of the electron in vacuum and m_e is the rest mass of the electron), meaning $\sum n_i \sigma_i(\omega) \cong n_e \sigma_e(\omega)$ $\to n_e \sigma_{Te}$, then Puthoff obtains a relationships between the total density in the point $P(r)$ and the CZPF density:

$$\rho_P(\omega) = \rho(\omega) n_e \sigma_{Te} R_{comm}. \tag{10}$$

The communication radius, R_{comm}, is defined as:

$$R_{comm} = \lim_{z\to\infty} r(z). \tag{11}$$

If $\rho_P(\omega) = \rho(\omega)$ then from (10), we get a relationship between the communication radius, the particles density (due to the free electrons) and the Thomson scattering cross section

$$R_{comm} = 1/\left(n_e \sigma_{Te} \right). \tag{12}$$

The same result is obtained if the infinite expanding models of the universe were used. Such models were developed by the mathematician V.

Vâlcovici (1958) and harmonize the empirical expansion law (Hubble's law) with the special relativity theory [25]. In an 'infinite expanding universe' model, the phenomenon of limitation of the "communication" radius (or the radius of the horizon) manifests itself through Doppler Effect. The Doppler Effect is determined by the radial expansion displacement of the sources, with respect to the observation point. The problem is later resumed in 1963 by H. Bondi and, independently, by Nicolae Ionescu-Pallas [26].

In the situation of an infinite universe model, the exponential attenuation of the intensity of the scattered radiation introduces some attenuation distance for each microscopic component. In this case, accurate reproduction of the spectral density (1) is obtained irrespective of the type of particles that scatter CZPF and their density [20].

Inside CZPF, the background of electromagnetic waves having zero temperature is a possible model of the sub-quantum environment which induces, through interaction, the quantum and relativist properties of the microscopic systems. It is this very background that determines the electromagnetic interactions and thus, implicitly, the quantum effects.

A detailed analysis of the cosmological constraints is performed by Wesson in his work "*Cosmological constraints on the zero-point electromagnetic field*" [24]. According to Wesson, the dynamic generation of the background in the universe implies a correlation with the cosmological constants. In general relativity the background either does not exist or, even if it exists, it doesn't bend the space. The fact that such an energy density doesn't have gravitational effects implies changes both in quantum physics and in the gravitational interaction theory.

2.2. Theoretical applications

The existence of a physical vacuum that can be modeled as ZPF or CZPF can describe phenomena and properties of microscopic and macroscopic physical systems. Thus, we will further present the most representative phenomena in this direction: the Casimir effect, the Lamb shift, Liquid Helium, the Zitterbewegung, the inertial mass and the gravitational mass, spontaneous emission, the fundamental state of the harmonic oscillator, the ground state of the Hydrogen atom, the Unruh effect and the wave-particle dualism.

The Casimir effect. The Casimir effect consists in an attraction phenomenon between two conductors placed in vacuum. This effect was theoretically described by physicist Hendrik B. G. Casimir in 1948 [11], in quantum physics, based upon the zero fluctuations of the physical vacuum [27]. The theoretical hypothesis was experimentally validated for the first time by M. J. Sparnaay [12] in 1958, and confirmed by subsequent experiments [28].

The Casimir effect for conductive spherical shell [29], for a dielectric plate and dielectric spherical shell [30] was also studied theoretically. We emphasize that the effect occurs no matter the shape of the plates / surfaces or the material [31].

The Lamb shift. The phenomenon consisting in modifying the energy levels of the quantum systems (particularly atoms) throughout the interaction between these particles and ZPF is known as the Lamb shift. This effect was experimentally observed in 1947, by W. E. Lamb and R. C. Rutherford [32]. This phenomenon can be explained both in QED as well as in SED [33].

Liquid Helium. The experimental finding that the liquid helium at the vapor pressure doesn't solidify even if it is cooled to near 0K temperatures [34] cannot be explained unless we admit that the interaction between the atoms and ZPF and the induced oscillation movement is more powerful than the attraction forces (of Van der Waals type) between the atoms.

The Zitterbewegung. According to the quantum relativistic theory of the electron [39], there is a random/stochastic internal movement (*Zitterbewegung*, in German) that cannot be explained otherwise than through the interaction between the electron and ZPF [35]. This phenomenon was experimentally observed [36].

The inertial mass and the gravitational mass. The mass, as a measure of the mechanical inertia, is a property of the elementary particles. To explain this property, the physicists proposed several phenomena. Starting from Mach principle, Sciama demonstrates that the mass is an effect of the interaction of one particle with all the other particles in the Universe [37]. After the development of SED another proposal was made, namely the hypothesis of generating the mechanical inertia as effect of the interactions between the particles and CZPF [38].

Spontaneous emission. In quantum electrodynamics the spontaneous emission phenomenon is explained as effect of the interaction between the atomic electrons and ZPF [39]. In SED the same spontaneous emission is considered as an emission stimulated by ZPF [40].

The fundamental state of the harmonic oscillator. The interaction between the harmonic oscillator and CZPF can explain the fundamental state of the harmonic oscillator within the classical theory [8, 14, 15].

The fundamental state of the Hydrogen atom. The interaction between the hydrogen atom and CZPF can explain the stationary states of the hydrogen atom within the classical theory [8, 9].

The Unruh effect. This effect [41] consists in the perception/measurement from an uniformly accelerated observer of a temperature equilibrium thermal radiation, which is proportional with the acceleration a:

$$T = \frac{\hbar a}{2\pi c k_B}, \tag{13}$$

with k_B or k the Boltzmann constant.

Both within QED and in SED the Unruh effect is considered as a relativistic effect. For the accelerated observer, the ZPF background transforms into a thermal background having the temperature proportional with the acceleration of the observer [42].

The wave-particle dualism. In his work "*The wave properties of matter and the zero-point radiation field*", de la Peña and Cetto explain the dual behavior of the microscopic systems in SED [43]. The authors propose a particle model that, when interacting with the CZPF background, gets a vibration movement having an angular frequency $\omega_C = mc^2/\hbar$ (i.e. the Compton frequency). As a result, the particle resonates with the background's waves having that same frequency. For a motionless particle, a stationary wave/packet is formed, having the angular frequency proportional to the rest mass. During its movement, a modulated packet of waves appears, having the group speed equal to the particle's speed. The equation that describes the stationary state is Schrödinger's stationary equation which, in relativistic context, is also known as the Klein-Gordon equation. The model is a development of the works of Surdin and Kracklauer [44]. The same problem is resumed by Haisch and Rueda in "*On the relation between a zero-point-field-induced inertial effect and the Einstein-de Broglie formula*", given the context of the inertial effects of the background over the accelerated particles [45].

In the recent papers: De Lorenci and Ribeiro demonstrates that the thermal motion of a charged particle is affected by the vacuum modified by the presence of a wall and the kinetic energy of the particle can increase but also decrease under the action of the modified vacuum [46]; Rasti and Meyer [47] studies the strong influence of zero-point energy for the hydrogen-ordered crystalline ice phases and Knoll proposes a model for dark matter as a modification of the vacuum properties by baryonic matter [48].

2.3. Technological applications

We will continue to make some clarifications on the technological tests that exist to capture and use ZPE. Most methods have in common the attempt to produce a polarization at the ZPF / CZPF level and to collect the resulting energy. In 1892 N. Tesla made the following statement [49]: "Throughout space there is energy. Is this energy static or kinetic! If static our hopes are in vain; if kinetic — and this we know it is, for certain — then it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of nature."

In December 1892, after three years of experiments, ***Nicola Tesla*** announced the discovery of a new form of energy, that he called Radiant Energy [50]. This energy can be accumulated, taped and used in driving motors or other devices, or it may produce, at times, very short but powerful DC discharges, as shown in his patents [51, 52]. Radiant Energy is present everywhere in Earth's atmosphere, coming from various sources, most of them natural (solar radiations, cosmic rays, lightning etc.) and consist in large spectrum EM waves, beta radiation and possibly other causes. In a recent article, Professor Manu Mitra shows that these circuits "can generate electricity to charge an ordinary inverter battery continuously" and "if some of the Towers like Wardenclyffe are installed then significant amount of electricity can be generated and can be used for household and small industries" [53].

Since 1984, ***John Bedini*** [54] has sought to use Tesla's ideas on radiant energy by capturing very short and high voltage pulses, obtained by discharging some coils. The coils were charged from a low voltage direct current source. These pulses were captured in a circuit with capacitors which were then discharged in a low impedance circuit, namely a battery. These discharges are made very quickly and the resulting currents have high values. Intermittent DC pulses allow the expression of electrical inertia in a system, like a hidden flywheel that keeps the pulse. The inertial effects of electrical pulses accumulate in the battery and will continue to charge the battery after the charger has been disconnected. John Bedini patented this method [55]. He presented his final model of this device in 2014 at the Energy Science and Technology Conference. A group of researchers from Rajamangala University of Technology Rattanakosin, in Thailand, made in 2018 both Bedini's model and his own model and obtained a battery COP=1.6 and COP=1.8 respectively [56].

Kenneth R. Shoulders was an electronics engineer, experimental physicist, and inventor. He was internationally recognized as the "Father of Vacuum of Microelectronics" and is well known as a founder of vacuum nanoelectronics, for his work on field emission active devices [57]. He created a very original electronic device, on which he performed experiments by sending ultra-short high-voltage pulses and observed the creation of localized charges, spherical form and hollow, with a diameter typically between 5 and 15 μm, formed by a accumulation of 10^8 - 10^{11} electrons, which he called "Electrum Validum" ("strong electron") [58]. These are now called "High-Density Charge Clusters" or "Condensed Plasmoids" [59]. This finding defies the concept that such things cannot occur due to the large repulsive forces that these electrons should determine on each other. Some researchers believe that these clusters are connected to the ZPF [60]. Between 1980 and 2010 he studied their behavior, lifespan, interactions with various metals, etc. and received a number of patents on this field [61-64].

More and more researchers have sought to find different configurations to use Casimir force. Cole and Puthoff [13], analyzing the thermodynamics involved in the Cassimir effect, believe that, theoretically, energy can be extracted from the vacuum using Cassimir forces. Davis and Puthoff [65] consider that the theoretical results do not unequivocally support the experimental results (other than those using the Casimir effect) of extracting energy from the vacuum. Dmitriyeva and Moddel [66] presented the results of the experimental verification of the energy extraction from Casimir cavities when the appropriate gas flows through them [67]. The experimental results, the observation and measurement of infrared radiation, cannot be explained on the basis of thermodynamic phenomena. For this reason, it is accepted that infrared radiation may be the effect of vacuum energy extraction.

In a recent paper [68], Moddel and Dmitriyeva consider that there are three classes of phenomena through which energy can be extracted from the vacuum: nonlinear processing of the zero-point field [69, 70, 71], mechanical extraction using Casimir cavities [11, 72, 73] and the pumping of atoms through Casimir cavities [74]. The first two classes violate the principles of thermodynamics and for the third class the experimental results are inconclusive.

The February 2017 issue of Nature Photonics [75] presents a silicon chip that intelligently uses a set of micrometric-sized shapes engraved on the plates. By lithography, the shape of all the components was made, the beam, the movable electrode, the T protrusions, the comb actuator. The whole structure looks like two tooth plates that join together through a small space of about 100nm. As the boards approach, the Casimir force enters the game and causes a repulsive force to appear. T-shaped silicon teeth are the ones that generate this force.

There is currently a wide variety of patents using ZPE and ZPF. However, their corresponding applications are not as numerous, but they certainly exist, as we have shown above.

3. The aim and objectives of the study

The objectives of this study are to demonstrate that all these phenomena described in sections 2.2. and 2.3. result from the fact that fundamental particles are the simplest systems that extract energy from vacuum. This discovery guides research for possible theoretical and practical (technological) applications.

Thus, the problem of methods and technical systems that extract energy from vacuum is reduced to the microscopic modelling of the extraction phenomenon.

In the paper we demonstrate that, at the microscopic level, the primary vacuum energy extractor is the elementary particle (especially the electron and the proton).

4. Power extracted by the fundamental systems from the CZPF radiation background. Technological limits.

4.1. Elementary particle as a fundamental extractor of vacuum energy

All these manifestations of ZPF get a coherent explanation if we consider the elementary particles as microscopic systems which extract energy from ZPF. The extracted energy is the one that intervenes in the known interactions.

A first model of the way the electron extracts energy from ZPF is presented in the work "*Classical Model of Electron in Stochastic Electrodynamics*" [7]. The motionless electron is modelled as an electrical bi-dimensional oscillator that scatters CZPF. When the center of the oscillator's mass is motionless, it absorbs the energy of the background waves and emits some of this energy as spherical waves. At equilibrium the absorbed power equals the emitted power, meaning that the oscillator scattered the ZPF's background. This primary scattering, gathered for all the electrons in the Universe (see the second section of this paper!), regenerates the ZPF background. The primary radiation interacts with another electron (the test electron) shaped as an oscillator and, by secondary scattering (absorption-emission), it produces the electrostatic type of interaction, meaning the Coulomb force. The secondary scattered radiation has an energy density proportional with r^{-4} [7] and is the energy extracted from the vacuum by the test electron, since it determines the change of its translation movement through the action of the Coulomb force. On its turn, the test electron produces the primary scattering of ZPF which is secondary scattered by the first electron and so determines the Coulomb interaction type over it. We emphasize that the extracted power - and so by default the detected power in our electromagnetic world - is the power corresponding to *the secondary scattering*.

According to [8], the ratio between the secondary scattered energy $(W_s = e^2/r)$ and the primary one $(W_p = P_p \times (R_0/c) = (2e^2 m_e^2 c^2/(3\hbar^2)) \times (R_0/c))$, by an electron placed at a distance r from another electron, during the time $T_0 = R_0/c$ equal to the age of the Universe, depends both upon the radius of the Universe (in the models considering an infinite radius, R_0 is the distance of attenuation by scattering), the classical radius of the electron $r_e = e^2/(m_e c^2)$ and the distance between the two electrons:

$$\frac{W_s}{W_p} = \frac{3}{2}\frac{r_e^2}{rR_0}\left(\frac{\hbar c}{e^2}\right)^2 = \frac{3}{2\alpha_e^2}\frac{r_e^2}{rR_0}, \alpha_e = \frac{e^2}{\hbar c}. \tag{14}$$

This ratio has maximum value for $r \cong r_e$ (in this situation the secondary scattered energy approximates the rest energy of the electron, $e^2/r_e = m_e c^2$)

$$\left(\frac{W_s}{W_p}\right)_{\max.} = \frac{3}{2}\frac{r_e}{R_0}\left(\frac{\hbar c}{e^2}\right)^2 = \frac{3}{2\alpha_e^2}\frac{r_e}{R_0} \cong 10^{-38}. \quad (15)$$

According to this model of the electron*, the extracted energy by a rest electron is its rest energy*, in fact the detectable energy by the measuring devices (which does produce observable effects by means of the measuring devices).

This model, though, does not explain the reason for which the free electron, in motionless state, has scattering cross section of the electromagnetic radiation independent from the wave's angular frequency (the Thomson cross section) while, related to the ZPF radiation, has a scattering cross section that depends upon the angular frequency (see formula (1) in the already cited paper [7]).

The model can still be improved if we use the hypothesis that, for a charged particle, particularly the electron and its corresponding anti-particle - the positron, *the electrical charge is nothing else but the measure of the capacity of this system to scattered the background of the ZPF*. This hypothesis fundaments itself upon the acoustic analogy [76], for which a bubble in a fluid spreads the acoustic waves and this acoustic field produces an interaction force of type $1/r^2$ over another bubble, namely the Bjerkenes secondary forces [76, 77]. It follows that we can model the electron as a bubble in the vacuum, that scatters the electromagnetic background. When the center of the bubble is at rest, the surface of the bubble executes radial oscillations by absorbing the energy of the waves in the background, and also emits part of this energy as spherical waves. This primary scattering gathered for all the electrons in the Universe regenerates the ZPF background while the secondary scattering over other electrons generates the electrostatic interaction. This model explains why the motionless electron has its scattering cross section dependent upon the angular frequency and why does it have an own angular frequency, as well (the bubble's natural angular frequency ω_0). It follows that the radial oscillations of the bubble, corresponding to its natural angular frequency, is the Zitterbewegung movement in the quantum model formulated by Dirac [78], $\omega_0 = \omega_{Ce} = m_e c^2/\hbar$. This model also establishes a relationship between the equilibrium thermal radiation, relativity and the electrical charge, according to the suggestions made by T. H. Boyer [79]. We can improve the model by solving the problem of the relativistic forced oscillator and the non-quantum relativistic scattering [14, 80, 81].

It follows from the literature [9, 20, 21, 22, 24] that, the zero background (CZPF) does not produce the bending of the space-time since this bending can only be determined by the energy extracted from the vacuum, by what we denote as particles, meaning the measurable energy while interacting with the measuring devices which are made from particles. This way the discrepancy between the calculated and the measured cosmological constant can be explained [18, 19].

There is a link between the parameters of the background and the cosmological ones to the extent that the cosmological parameters are connected to the microscopic parameters (of the particles that interact with the background and make up the universe, according to the universe's models). The background is generated by the particles and, on its turn, it generates particles through of the interference-diffraction phenomenon.

It turns out that the elementary particles are the primary, fundamental converters, which extract energy from the ZPF and then redistribute it (ZPF), including through the interactions that take place between different charged particles. I will try to prove this in the next chapter.

4.2. Power extracted by a charged particle from the CZPF radiation background

To calculate the power extracted by a charged particle from the CZPF radiation background we will use the electrically charged particle model proposed in the paper [7]. In this paper, the charged particle is modelled as a two-dimensional oscillator. Based on this model it was demonstrated in classical physics, that the electrostatic interaction between two electrically charged particles is the effect of the interaction of the two particles (particularly electrons) with the CZPF radiation background. The oscillator with mass m and electric charge $q = nq_e$, $n = 1, 1/3, 2/3$ (to include electrons, protons, and quarks) is characterized by an interaction cross section with an electromagnetic plane wave [7]:

$$\sigma_n(\omega) = \frac{8\pi R_n^2 \omega^4}{3\left[\left(\omega_0^2 - \omega^2\right)^2 + \Gamma_n^2 \omega^6\right]} . \tag{16}$$

In previous relationships, $R_n = n^2 q_e^2 / \left(4\pi\varepsilon_0 mc^2\right) = n^2 e^2 / \left(mc^2\right)$ is the electrostatic radius of the particle, $\Gamma_n = 2n^2 e^2 / \left(3mc^3\right) = 2R_n / (3c)$ is the damping constant, ω_0 is the natural angular frequency of the oscillator and ω the angular frequency of the plan electromagnetic wave [82].

The power scattered from the charged particle is calculated using the Eq. (7) in the paper [7] generalized for any particle with mass m and charge $q = nq_e$:

$$P_{sn} = \frac{2c}{3} \int_0^\infty \rho(\omega) \sigma_n(\omega) d\omega . \tag{17}$$

Substituting Eq. (1) and Eq. (21) in Eq. (22), results:

$$P_{sn} = \frac{8\hbar R_n^2}{9\pi c^2} \int_0^\infty \frac{\omega^7}{\left(\omega_0^2 - \omega^2\right)^2 + \Gamma_n^2 \omega^6} d\omega = \frac{2\hbar \omega_0^3 R_n}{3c} = n^2 \frac{2\hbar \omega_0^3 e^2}{3mc^3} . \tag{18}$$

Imposing the Zitterbewegung condition for the particle at rest, $\hbar\omega_0 = mc^2$ [7, 78], in Eq. (23), results:

$$P_{sn} = n^2 \frac{2\hbar\omega_0^3 e^2}{3mc^3} = n^2 \frac{2m^2c^3e^2}{3\hbar^2}. \tag{19}$$

For the electron, with: $m = m_{0e} \cong 10^{-30}\,\text{kg}$, $n = 1$, $c \cong 3\cdot 10^8\,\text{ms}^{-1}$, $e^2 \cong 10^{-28}\,\text{kgm}^3\text{s}^{-2}$ and $\hbar \cong 10^{-34}\,\text{kgm}^2\text{s}^{-1}$, the power is:

$$P_{se} = \frac{2m_e^2c^3e^2}{3\hbar^2} \cong 18\times 10^4\,\text{W}. \tag{20}$$

The power scattered by the $N = M/m_p \cong 10^{81}$ electrons in the finite Universe [24] is very high. However, this power is not manifested (not observed) directly. The total scattered power $P_{tse} = 2Nm_e^2c^3e^2/(3\hbar^2) \cong 18\cdot 10^{85}\,\text{W}$ is redistributed in the finite Universe and reconstitutes / reproduces the CZPF radiation background.

The power that manifests in the Universe, i.e. the power extracted from the CZPF, is a fraction of the power scattered by an electron in the form of rest energy and in the form of interaction energy. The electron, as an oscillator, extracts a fraction of the energy of the CZPF radiation background and increases its oscillation energy (amplitude of oscillations) until the equilibrium condition is met, the absorption power (P_{ae}) is equal to the emission power (P_{ee}) and therefore to the scattering power (P_{se}): $P_{ee} = P_{ae} = P_{se}$.

In the equilibrium condition, the total energy absorbed is the rest energy (when the center of mass of the oscillator is at rest for the external observer) which meets the Zitterbewegung condition $\hbar\omega_{0e} = m_{0e}c^2$. For the manifestation of the second form of extracted energy it is necessary to have at least one other electron to absorb and emit (scatter) this power. The power scattered by the second electron is observed as an electrostatic interaction between the two electrons [7]. The interaction changes the rest state of the center of mass of the two electrons. In order for the center of mass of the two electrons to move, i.e. the electrons also have kinetic energy, they must absorb additional energy from the CZPF background equal to the kinetic energy. The scattered power (P_{se}) is dependent on the distance between the two electrons

$$P_{se}(r^2) = \int_0^\infty dS(\omega, r^2)\sigma_{2is}(\omega) = \int_0^\infty \frac{dS_0}{4\pi r^2}\sigma_{2is}^2(\omega) = \frac{c}{24\pi r^2}\int_0^\infty \rho(\omega)\sigma_{2is}^2(\omega)d\omega. \tag{21}$$

According to paper [7], the significances of the notations are: dS_0 spectral intensity for isotropic background, $dS(\omega, r^2)$ spectral intensity for primary scattering, $\sigma_{2is}(\omega)$ isotropic scattering cross-section for two-dimensional oscillator, in according to Eq. (17) of [7]. Replacing in Eq. (21) the expressions for the spectral density (1) and the section for the two-dimensional oscillator (Eq. (6) of [7]), result

$$P_{se}(r^2) = \frac{c}{3\pi r^2}\int_0^\infty \frac{\hbar\omega^3}{\pi^2 c^3}\left[\frac{8\pi R_e^2\omega^4}{3\left[\left(\omega_{0e}^2-\omega^2\right)^2+\Gamma_e^2\omega^6\right]}\right]^2 d\omega = \frac{\hbar\omega_{0e}e^2}{m_e c r^2}. \qquad (22)$$

This power corresponds to the electrostatic force between the two electrons $P_{se}(r^2) = F_e c$. (23)

Comparing Eqs. (22) and (23) and taking into account the equilibrium condition (Zitterbewegung condition) we find the expression of the electrostatic force between two electrons $F_e = e^2/r^2$ obtained in the paper [7]. For the moving electron, the scattered power is higher because the equilibrium condition is reached when the observed mass (measured mass) is higher (it also includes the power corresponding to the kinetic energy) and depends on the velocity of the center of mass *v:*

$$\hbar\omega_e = m_e(\upsilon)c^2 > \hbar\omega_{0e}. \qquad (24)$$

The additional power absorbed by the moving electron (the kinetic power P_{ke}) is $P_{ke}(r^2) = F_e\upsilon$.

For the moving electron, as an oscillator, the spectrum of the electromagnetic radiation of the CZPF radiation background and the natural angular frequency changes according to the transverse Doppler effect

$$\omega(\upsilon) = \frac{\omega}{\sqrt{1-\upsilon^2/c^2}}, \quad \omega_e = \omega_e(\upsilon) = \frac{\omega_{0e}}{\sqrt{1-\upsilon^2/c^2}}. \qquad (25)$$

It follows that the electron model, as an oscillator that scatters the CZPF background, also explains the wave-particle dualism founded by Louis de Broglie [83].

4.3. The power extracted by complex systems and technological limitations

The simplest systems of charged particles are atoms of different elements. The power extracted by these systems from the CZPF radiation background is much lower than that extracted by the fundamental particles (P_{se}).

One system that occurs naturally in the Universe is the hydrogen atom made up of proton and electron. To calculate the power extracted by this system from the CZPF radiation background, we model the hydrogen atom as a system consisting of two two-dimensional oscillators with natural angular frequency, in the ground state, $\omega_{0H} = m_e e^4/\hbar^3$ [8].

The two oscillators have the same value of the electric charge $e_p^2 = e_e^2 = e^2$ and are different in their mass, $m_p \cong 1836 \cdot m_e$.

The power extracted by the electron in the hydrogen atom (P_{seH}) is calculated using the power of a two-dimensional oscillator with mass m_e and the natural angular frequency $\omega_{0H} = m_e e^4/\hbar^3$ [10],

$$P_{seH} = \frac{2\hbar\omega_{0H}^3 e^2}{3m_e c^3} \cong 2.2 \times 10^{-10}\,\mathrm{W}. \quad (26)$$

Comparing (26) with (20), it results $P_{seH} << P_{se}$.

The power extracted by the proton from the hydrogen atom is much lower [8], because the mass of the proton is much higher, $m_p \cong 1836 \cdot m_e$, and the natural pulsation of the attached oscillator is the same.

The power extracted by the proton in the hydrogen atom (P_{spH}) is calculated using the power of a two-dimensional oscillator with mass m_p and the natural angular frequency of the attached oscillator is the same, $\omega_{0H} = m_e e^4 / \hbar^3$,

$$P_{spH} = \frac{2\hbar\omega_{0H}^3 e^2}{3m_p c^3} = \frac{2\hbar\omega_{0H}^3 e^2}{3 \times 1836 \times m_e c^3} \cong 1.2 \times 10^{-13}\,\mathrm{W},\; P_{spH} < P_{seH} << P_{se}. \quad (27)$$

In conclusion, the power scattered by electrically charged particles and especially by the electrons in the Universe is the power to which we have access and which we can extract through various technically designed physical systems. Any proposal for a device that draws energy from the CZPF radiation background must take into account the limitations set out above.

5. Conclusion

The physical investigation of the vacuum, modelled as a photon system (in QED) and as an electromagnetic wave system (in SED), highlights two essential properties. The two properties are: the reality of the physical vacuum as a system that has energy and the existence of microphysical systems (fundamental particles, i.e. the electron and proton) as physical systems that extract energy from the vacuum. The energy extracted by fundamental particles is the energy involved in fundamental physical interactions, as well as the energy measured in our universe.

The power scattered by electrically charged particles and especially by the electrons in the Universe is the power to which we have access and which we can extract through various technically designed physical systems. Thus, the electrical charge is nothing else but the measure of the capacity of these systems to scatter the background of the ZPF. We calculated the powers extracted by an electron and a particle system, the hydrogen atom, from the background CZPF.

Any proposal for a device that extracts energy from the CZPF radiation background must take into account the limitations set out above.

The fundamental interaction on which most technological applications for energy production are based, i.e. the electrostatic interaction and implicitly the electromagnetic one, is the effect of the extraction of energy from the vacuum by the charged particles. It follows that the fundamental particles are the fundamental extractors of energy from the vacuum. The energy involved in generating larger systems: the atoms, the molecules and the nanotechnological systems comes from this primary energy extracted from the vacuum by particles.

Unlike the theoretical and experimental proposals presented so far by various authors, we show that the correct way to solve the problem of energy extraction from vacuum is to consider that elementary particles and their systems (the atoms) are fundamental extractors. It remains to be investigated theoretically and experimentally which particle configurations and atomic systems (at the nano and macroscopic levels) maximize energy extraction.

The analysis performed, from the point of view of physicists and engineers, aims to stimulate the investigations made by various researchers to imagine, design and manufacture microscopic (nanotechnology) and macroscopic devices to extract energy from the vacuum. It also explains some results that were observed and highlighted by researchers and engineers worldwide, even if they could not fully explain them at that time [8, 12, 23, 50-64, 84].

We hope that these results will contribute to the realization of further experiments by physicists and engineers, to bring clarifications in this direction.

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